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INTELLIGENT EVENT IDENTIFICATION SYSTEM.
VOLUME II: USER'S MANUAL

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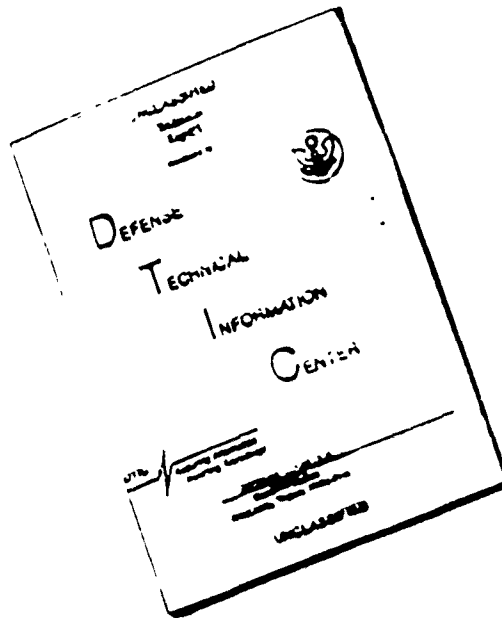DONALD H. ECKHARDT, Director
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13. ABSTRACT (Maximum 200 words)

The objective of this project is to design and develop an Intelligent Event Identification System, or ISEIS, which will be a prototype for routine event identification of small explosions and earthquakes and to serve as a tool for discrimination research. The first part of this report gives an overview of the system design and the results of a preliminary evaluation of the system on events in Scandinavia and the Soviet Union. The system was designed to be highly modular to allow the easy incorporation of new discriminants and/or discrimination processes. Because the main objective of the system is the identification of small events, most of the initial ISEIS prototype discriminants utilize regional seismic data recorded by the regional arrays, NORESS and ARCESS. However, ISEIS can easily process other regional array data (e.g., from GERESS and FINESA), as well as data from three-component single stations, as more of this data becomes available. The second part of this report is entitled Intelligent Event Identification System: User's Manual, and gives a detailed description of all the processing interfaces of ISEIS. The third part of this report is entitled Intelligent Event Identification System: Software Maintenance Manual, which describes the ISEIS software from the programmer's perspective and provides information for maintenance and modification of the software modules in the system.

14. SUBJECT TERMS Discrimination Regional propagation Expert system	NORESS ARCESS High-frequency Ripple-fire	Coda Waveform matching Dynamic time warp	15. NUMBER OF PAGES 142
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INTELLIGENT EVENT IDENTIFICATION SYSTEM

USER'S MANUAL

1.0 INTRODUCTION

This document is the Reference Manual for the operation of the Intelligent Event Identification System (ISEIS). This manual, plus the ISEIS Maintenance Manual, provides the essential information for the operation and software maintenance of the system.

This section presents a bibliography of other relevant documentation and explains how to initiate the system. Section 2.0 presents a general overview of ISEIS and the basic concepts used in the manual. Section 3.0 discusses guidelines and features which are common to most of the subcomponents of the system. Thereafter, information about the various functions of the system are discussed. Section 4.0 covers the operation of the Map Display Process. Section 5.0 describes the Top Level Spreadsheet Process, which is the primary controlling interface for the entire system. Section 6.0 describes the Intermediate Level Discriminant Processes, which provide explanation facilities for the discrimination results. Finally, Section 7.0 discusses the operation of the Low Level Discriminant Signal Analysis and Display Processes.

1.1 DOCUMENTS

This system resulted primarily from research described in the following papers and reports:

Baumgardt, D.R. (1990). Knowledge-based seismic event identification using seismic event case knowledge and explanations, *SAS-TR-90-36*, SBIR Phase I Technical Report, ENSCO, Inc., Springfield, VA.

Baumgardt, D.R. and G. Young (1990). Regional seismic waveform discriminants and case-based event identification using regional arrays, *Bull. Seism. Soc. Am.*, **80**, 1874-1892.

Baumgardt, D.R. and K.A. Ziegler (1989). Automatic recognition of economic and underwater blasts using regional array data, *ENSCO Technical Report to SAIC*, ENSCO, Inc., Springfield, VA.

Baumgardt, D.R. and K.A. Ziegler (1988). Spectral evidence for source multiplicity in explosions: application to regional discrimination of earthquakes and explosions, *Bull. Seism. Soc. Am.*, **78**, 1773-1795.

Discrimination studies by other groups which have influenced this design include the following:

Bennett, T.J., B.W. Barker, K.L. McLaughlin, and J.R. Murphy (1989). Regional discrimination of quarry blasts, earthquakes and underground nuclear explosions, Final Report, *GL-TR-89-0114*, S-Cubed, La Jolla, CA.

Pulli, J.J., and P.S. Dysart (1987). Spectral study of regional earthquakes and chemical explosions recorded at the NORESS array, Technical Report, *C87-03*, Center for Seismic Studies, Arlington, VA.

The algorithm for the Dynamic Time Warp coda-shape template matcher is described in the following:

Myers, C.S. (1980). *A comparative study of several dynamic time warping algorithms for speech recognition*, Masters Thesis, Massachusetts Institute of Technology.

Information about the maintenance of the ISEIS software can be found in the following document:

Intelligent Event Identification System Maintenance Manual, ENSCO, Inc., 1991.

The expert system shell used in this system is the C Language Production System (CLIPS), distributed to the public domain by NASA. Information about the implementation of CLIPS and interfacing CLIPS to other programs is provided in the following document:

CLIPS Reference Manual, Version 4.3 of CLIPS, Artificial Intelligence Section, Lyndon B. Johnson Space Center, JSC-22948, 1989.

ISEIS has been developed to be a backend process for the Intelligent Monitoring System (IMS), and in particular, the Analyst Review Station (ARS) of the IMS. Events and parameters determined by the IMS and ARS are passed to ISEIS through the database. Documentation which describes the functionality and operation of the ARS is the following:

Intelligent Monitoring System, Analyst Review Station Reference Guide, Documentation Set, September 1991, SAIC-91/1182, Science Applications International Corporation, San Diego, California.

ISEIS uses the Oracle RDBMS and the core relations of the 3.0 CSS database described below:

Anderson, J., W.E. Farrell, K. Garcia, J. Given, H. Swanger (1990). Center for Seismic Studies Version 3 Database: Schema Reference Manual, *Technical Report C90-01*, September 1990.

1.2 STARTING ISEIS

The ISEIS software tree begins under /home/iseis. After setting up user login iseis, ISEIS can be started up by logging in under the name 'iseis' and answering 'Y' to the 'Start ISEIS System (Y/N)?' prompt. At this point, a '.StartIseis' UNIX script starts all necessary IPC processes, X window servers and initial ISEIS display processes. It first checks to see if the Dispatcher is currently running, and starts it if it is not. It then insures that only one Monitor process is running on each of the member systems in the ISEIS network. After the Monitor processes are running, it finds the set of unique X window display names by accessing the X_DISPLAY fields in the MachAlloc file. All necessary X window displays are started and then the initial ISEIS processes are started.

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If all goes well, starting the ISEIS system should initialize all the ISEIS processes specified in the PROC_LIST environmental variable. If these processes do not start up normally, then possible causes may include the following:

1. The X_DISPLAY field for the given process in the MachAlloc file is set to NONE.

2. The X_DISPLAY specified in the MachAlloc is not active.

3. The Dispatcher is not running.

4. A Monitor process is not running on each ISEIS system.

5. The Dispatcher and Monitors could be in a "disk wait" system state indicated by a status of "D" when the UNIX ps command is invoked.

6. The executable images for the processes are not present in $HMD/$MACHINE/bin or this directory is absent.

Usually, typing 'StartIseis' will insure that most of the above conditions are met, but in cases where processes are in abnormal states, the offending processes must first be killed prior to re-starting 'StartIseis.' A user familiarity with the UNIX 'ps' and 'kill' commands is useful.

Note: The reader should refer to the ISEIS Maintenance manual or consult with the system administrator if problems arise with initializing ISEIS.

In cases where the user wants to start the ISEIS initial processes manually, the following commands will work from an xterm or console.

1. For Spreadsheet startup use:

    dsmain $W/eventFile.d $UI all -d X_DISPLAY

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2.   For the Interactive Map use:

        map $W/eventFile.d $UI -d X_DISPLAY

3.   For the RGB color editor use:

        RGBcolor 0 0 0 -USE_PNAME

In each case, X_DISPLAY should be one of the displays in the X_DISPLAY field in the system MachAlloc file. The RGB color editor must be run on a Stardent-type system and the Map and Spreadsheet processes must run on Sun-type systems. The Map cannot display on a Stardent-type X window display.

2.0 SYSTEM OVERVIEW

This section presents an overview of the ISEIS system and the basic concepts used throughout this manual.

2.1 ISEIS FUNCTIONALITY

The Intelligent Event Identification System (ISEIS) is a combined interactive and automated system for the identification of seismic events using primarily high-frequency seismic data. It uses the X Window System for all graphics and the Oracle relational database for data acquisition and storage of discriminant processing results. ISEIS uses the core relations of the Center for Seismic Studies 3.0 Database supplemented with additional relations specifically designed for discrimination processing. The Dispatcher, developed for the Intelligent Array System (IAS), is used for distributed processing, although the system can be started up from an ISIS message. ISEIS is menu/mouse-driven, which uses the mouse for selection/deselection, dragging on waveforms, incoherent beams, and spectra, and Macintosh style pulldown menus.

ISEIS is designed as a highly modular system to facilitate the modification of discriminant techniques and the addition of new ones. The main emphasis in the design of this prototype has been on the processing of high-frequency, regional array waveform data for the purpose of identifying seismic events at regional distances. Thus, most of the discriminants are derived from high-frequency waveform features. However, the modularity of the system will allow the future inclusion of additional discriminants of an event-parameter nature (e.g., event location relative to seismic areas, proximity to test sites, etc.) as well as more teleseismic discriminants. Moreover, although the initial ISEIS discriminants were designed to exploit data from the regional arrays, NORESS and ARCESS, the same processing methods developed for regional array data should also apply to single station data and other regional array data as they become available.

2.2 DISCRIMINANTS

Discriminants consist of a set of signal processing functions and rules which attempt to characterize the seismic event on the basis of its recorded signal characteristics. Discrimination begins with the processing of signals in certain ways to produce **features**, which are measurements made from waveforms or transformations of waveforms. After features have been

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extracted, they are stored in the database to be analyzed later by rules. A discriminant may obtain the feature in one of two ways: (1) when the discriminant is run, a signal processing function is applied to compute the feature; (2) the feature may have been computed previously and the discriminant may access the feature from the database. However, even in the first case, the feature value will be stored in the database, and subsequent application of the discriminant on the same data can actually access the feature from the database rather than computing it again.

2.2.1 Waveform Transforms

The three most important waveform transformations used in regional event discrimination by ISEIS are **incoherent beams, single spectra**, and **cepstra**. Incoherent beams are essentially envelope traces of the regional wavefc ms, computed by averaging the rms amplitude, computed in specified time windows (usually one second), across the array. In the case of single channel data, the envelope trace of the single channel waveform is computed. The computation of incoherent beams in ISEIS is discussed in detail in Section 7.2.1.

Array-averaged spectra are computed by first computing spectra on each channel of the array for designated phases and then averaging them across the array. Single spectra, which are used in the spectral-ratio and ripple-fire discriminants, are different than **continuous spectra**, in that the former are only computed for single windows on specific phases. Continuous spectra or **sonograms** are contour plots of spectra computed in multiple windows. For single channel data, of course, spectra for only a signal channel are computed. The computation of single spectra and continuous spectra are discussed in detail in Sections 7.2.2 and 7.4.1, respectively.

Cepstra are Fourier transforms of the log of the amplitude spectra. The independent variable of the cepstrum is called the **frequency**, which has units of time. If a spectrum has frequency domain periodicity, or spectral scalloping, the cepstrum will have peaks proportional to integer multiples of the inverse of the frequency interval between the peaks or troughs of the spectral scallops. ISEIS uses cepstral peaks as an indication of spectral scalloping caused by ripple-fired economic explosions.

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2.2.2 Features

Feature measurements are made from both incoherent beams and spectra. Amplitude measurements and time interval picks for different phases measured off of incoherent beams are called **stapicks**. Stapicks can begin at times picked by the analyst in the ARS but include a duration time, which is set in the various phase selection options in ISEIS. For the time duration of each stapick, the peak amplitude and the average amplitude over the time duration are both stored. The time duration is also used in the coda shape template matcher, Dynamic Time Warper (DTW), described in Section 7.3.4. The stapick time duration can also be used to define the windows to be used in the computation of single spectra for specific phases.

Stapick measurements made on incoherent beams of different phases are used in **amplitude ratio** measurements. ISEIS currently makes three amplitude ratio measurements: (1) **max P/S** which is the ratio of the maximum P (Pn, Pg, P) in any frequency band to the maximum S (Sn, Lg, S); (2) **HF Pn/Sn** which is the ratio of a high frequency amplitude of Pn to Sn; (3) **HF Pn/Lg** which is the ratio of high frequency Pn to Lg. The amplitude ratio discriminant interface is described in Section 7.3.1.

DTW also produces features, called **DTW distances**, which give a measure of the relative excitation of different parts of the waveform envelope. Distances are computed for the entire waveform, called **cumulative distances**, or for the time duration of specific phases, called **phase distances**. The match between a reference event and the new event is based on how small the various distances of separation are in the DTW match.

Feature measurements on spectra include average or peak amplitudes made in **spectral bins**, which are defined by a beginning and ending frequency. **Spectral ratios** between amplitude measurements in different spectral bins for the same phase give a measure of the relative frequency content of a phase. The spectral ratio interface is described in Section 7.3.2.

If a spectrum has a modulation, it will produce a **cepstral peak**, whose frequency is the most important feature measurement made on the cepstrum. The Multiple Event Recognition System (MERSY), described in Section 7.3.3, identifies ripple-fired events on the basis of time independent frequencies of cepstral peaks, indicative of a time independent spectral modulation.

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2.2.3 Rules

Rules in ISEIS are used to interpret the feature measurements in making decisions about the characterization of a seismic event. A **rule** is a collection of conditions and the actions to be taken if the conditions are met. Each discriminant has a set of rules, referred to as the **knowledge base**. The rules are coded in the CLIPS language, which also provides the **inference engine**, or the algorithm which interprets the rules and carries out the actions called for in the rules.

2.2.4 Model- and Case-Based Reasoning

The rules in ISEIS are used to do both model- and case-based reasoning in interpreting seismic events. **Model-based reasoning** is that which actually identifies events as a particular source type. The model is essentially a mechanism, in our case a set of rules, which takes as input the feature values and produces as output the event identification with some confidence. ISEIS identifies an event as one of the following: **earthquake, explosion, economic explosion**, or **unidentified**.

Case-based reasoning compares waveform features to events in the same region as the unknown event and determines how similar they are to the reference events. For case-based reasoning, ISEIS accesses historical events in the database, called **reference events**, for regions nearest to the unknown event, called **reference regions**. Reference regions are limited spatially by a maximum and minimum latitude and longitude which includes all the events attached to the region. The geographic center of the region is called the **region centroid** which is used in the selection of the closest region to an event. The user can define reference events and reference regions in the map interface, discussed in Section 4.0. The three classes of case-based identification are **similar, dissimilar**, or **unknown**.

Thus, model-based reasoning tries to determine source type, whereas case-based reasoning determines source affinities. Although case-based reasoning does not directly identify source types, it can do so indirectly if all the best matching reference events have been identified as a certain source type. A discriminant can be either a model-based discriminant, case-based discriminant, or both model-based and case-based.

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2.3 PROCESSING CYCLE

The basic processing cycle for either interactive or automated discrimination is the same. The first step is to process data in order to extract features and place them into the database. The second step is to then apply CLIPS rules to assess data status and identify the event.

2.3.1 Status Assessment

In the interactive application of a discriminant to an event, the event-discriminant pair is first **selected**. The procedure for selection from the Top Level Spreadsheet is explained in Section 5.0. The first process is to **assess** the discriminant data status. This primarily involves the execution of CLIPS rules which take assertions about the presence of certain data structures such as spectra, cepstra, arrivals, etc., and fire rules which determine the **data status**, which is an estimation of whether or not enough data is available for the discriminant to be executed. Data status rules determine whether or not the **necessary** and/or **sufficient** conditions are present to run a discriminant. **Necessary** conditions describe what minimal data must be present to run a discriminant at all. **Sufficient** conditions describe what additional criteria beyond the necessary conditions must be satisfied for the discriminant to be applied. For example, in running a spectral ratio discriminant, necessary conditions might be that spectra for a particular phase be present, whereas sufficient conditions might state that the signal spectra must exceed a specified minimum signal-to-noise ratio.

Data **status** can have one of three values: **complete, incomplete,** or **no data.** **Complete** means that all the data required to apply a discriminant are present, that is, that the necessary and sufficient conditions are all satisfied. **Incomplete** means that only the necessary conditions are satisfied but not the sufficient conditions. This means that the discriminant can be applied, but the results may not be very meaningful or may have low confidence. **No data** means that neither the necessary or sufficient conditions are satisfied, and the discriminant cannot be applied at all. If the data status is assessed as being incomplete or no data, then additional signal processing may have to be applied to try to upgrade the status.

2.3.2 Discriminant Execution

When the status is complete, then the discriminant can be **executed**. Execution of discriminants may involve additional signal processing and/or database access before the event identification CLIPS rules are actually fired. **Rule update** can be applied if it is determined that either no signal analysis is required or it has already been applied, and only the rules are executed. After the discriminant has been executed, the results are placed in the database and explanation data files are generated.

After all the discriminants have been executed for an event, then a **combined** discriminant is applied. **Combined** takes all the results and confidences of the individual discriminants and derives an overall decision and confidence for the event characterization. Combined must go through the same cycle of status assessment and execution as the individual discriminants. In the case of combined, the data status refers to whether or not all the necessary or sufficient discriminants needed for combined have been run for the event. Execution primarily involves accessing from the database the results and decisions for each of the individual discriminants and combining them in some way to make an overall event characterization.

All the criteria for the data status and for event characterization are defined in the CLIPS rules as assertions. They may be changed by the user by editing the CLIPS rule files, which are stored as files on disk. ISEIS provides a simple editing interface to the CLIPS rules which can be used by a user familiar to the CLIPS rules language to change rules or criteria.

2.3.3 Explanation of Results

ISEIS presents a three-tiered set of explanation displays for the results of discriminant processing on an event: **top level spreadsheet and map, intermediate level text**, and **bottom level data analysis**. As the user descends the tiers from the top to the bottom, the results are presented in a more data intensive manner.

The **top level spreadsheet/map** displays present an overview of the results of the event along with other events being processed and/or reference events. This is accomplished by making use of color coding and in the use of symbols plotted on the map. This high level display allows

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the quick evaluation of the results of the processing of several events at once on the spreadsheet and on the map.

The **intermediate level text** displays provide, in textual form, an explanation of the results of the status assessment and discriminant execution on any particular event. These explanations are reached by mousing on individual boxes in the spreadsheet display. Also, at this level, the user can view the trace of rule execution and edit the CLIPS rules themselves. When the rules are changed and saved, all succeeding assessments, in the case of status rules, and discriminant execution or rule update, in the case of event characterization rules, will use the changed rules.

The **bottom level data analysis** displays provide the most detailed explanations of the processing results for the particular event. These displays are reached either through the cells of the spreadsheet or through the **PROCESS** menu of the Spreadsheet. Moreover, these displays also allow the actual interactive execution of any of the signal processing functions of ISEIS. either for upgrading the data status or for providing input data to the event characterization rules.

3.0 GENERAL GUIDELINES AND FEATURES

3.1 PULLDOWN MENUS AND THE MENUBAR

All of the process windows of ISEIS provide a window, called the menubar, which contains a set of pulldown menus. Each of the pulldown menus provides a number of options for controlling the execution of a process or for displaying the results. The standard set of menus includes the following:

FILE - this menu has options which primarily control the opening and closing of databases and for exiting processes.

EDIT - edit menu allows the user to alter the way in which data or results are being displayed by the process and to edit the CLIPS rule files.

VIEW - view menu options control the various data display formats and what data is displayed.

SELECT - these menus allow the user to select the different parameters used in the execution of a process for a display.

EXECUTE - the menu which controls the actual running of a process.

PROCESS - primarily used in the top level display, this menu allows the user to select a particular bottom level data analysis function.

Although these menus are standard through ISEIS, they actually provide options specific to each process. A detailed explanation of all the menu options are provided in Sections 5.0 - 7.0.

3.2 ERROR/STATUS DIALOGS

ISEIS will display a variety of dialog boxes to the user to provide information about the current state of the system, warnings about possible problems, and error descriptions which explain why some process cannot be run. The dialog boxes contain both an icon symbol and a

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color code. A mouse click box is also provided to remove the dialog. The various dialog boxes are the following:

Information - This dialog is colored blue and displays a smiling face icon. The box will contain informative information about the state of the system.

Warning - This dialog is colored yellow and displays a smiling face icon with an exclamation mark. This dialog gives a warning about possible problems but does not stop execution of the process.

Question - This dialog is colored yellow and displays a smiling face icon with a question mark. The question must be answered before execution proceeds.

Fatal Error - This dialog is colored red and displays a sad face icon. Execution of the process cannot continue.

3.3 AREA SELECTION

Area selection in ISEIS provides the user with the capability of selecting an interval on a graph, which is usually either a waveform, incoherent beam. or a spectrum, for applying some process or making a measurement. Area selection is accomplished by moving the mouse while pushing the left mouse button. When the mouse button is released, the selected area will be blackened in. In most processes, another box (usually Enter) must then be moused. Area selection is used in ISEIS for selection time intervals on waveforms for execution of signal analyses, such as incoherent beam computation (Section 7.2.1), continuous spectra (Section 7.4.1), and continuous FK (Section 7.4.2), selection of phase intervals in the Phase Select options, such as in amplitude ratios (Section 7.3.1) and for spectra computation (Section 7.2.2), and for the selection of spectral intervals for spectral ratios (Section 7.3.2) and for spectral signal-to-noise ratio computations (Section 7.2.2).

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3.4 SELECTION FROM LEGENDS

Processes which require multiple selections, such as array channels for incoherent beamforming or spectral stacking, provide selection legends, which are similar to check boxes. The option is selected by mousing on the box next to the selection option, displayed as a text description. When the option is a selection, the box will be colored or darkened in.

3.5 PROCESS DISPLAY ICONS

Process icons are displayed by certain processes in ISEIS which are very time-intensive, including incoherent beam, continuous spectrum, continuous FK, and DTW. When the **EXECUTE** option is selected for the function, a separate process is initiated independent of the user interface display process which initiates it. Thus, the user can exit the user interface and do other analysis work until the time-intensive process has completed. When the time-intensive process has completed, it informs the user by placing an icon at the top right of the main window with a descriptive picture in the icon:

Single Graph (spectra, incoherent beams)

Three-dimensional graph (sonograms)

When the icon is moused, a user interface window is initiated which provides the user different options to view the results of the process.

3.6 X-WINDOW MANIPULATIONS

ISEIS allows the user to manipulate all the windows, such as moving and re-sizing windows. For details for how to manipulate windows for any window manager, see the window manager user's documentation.

4.0 MAP DISPLAY PROCESS

In this section, the Top Level Map Display process is described.

4.1 GENERAL DESCRIPTION

When the Top Level Map Display process is begun, the screen which will appear is shown below:
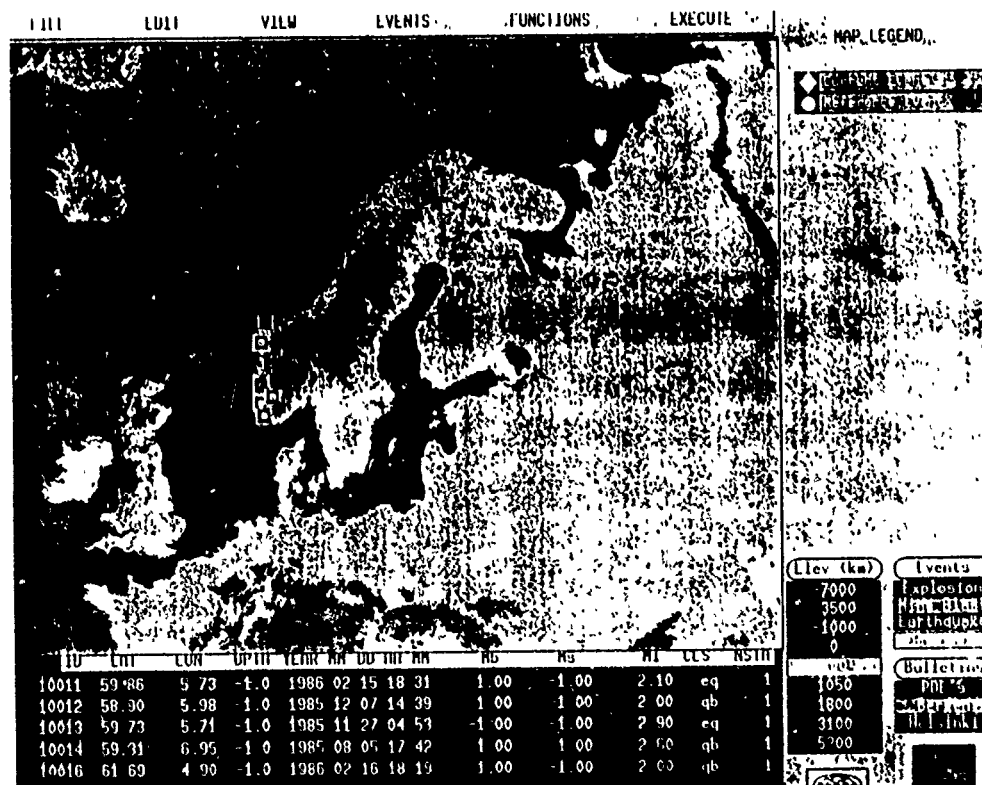
This display contains five subwindows: the menu window, the map display window, the bulletin display window, the message window, and the map legend window. The menu window across the top contains pulldown menus of the different options available to the Top Level Map process. The map window contains the actual plot of the map with all the additional geographical and event data plotted. The scrollable bulletin window contains a list of the event parameters for all the events currently active in the system. The message window at the bottom is the place where

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short textual messages are printed by the process. All these windows, with the exception of the message window, are sensitive to the mouse at various locations.

The map legend window is located to the right of all the windows discussed above. This window provides a description of the meaning of different event type symbol codes and color codes used in the map display. The most important color codes are those which represent event types, which are green for earthquake, orange for mine blast, red for explosion, and yellow for unknown. Different symbols are used to represent current events (diamonds), which are new events that are unidentified, and reference events (circles), which can be used for comparison.

4.2 MENUS

The menus on the map are designed to allow the user to display different maps and map overlays, to plot current and reference events on the map, to view the current seismic events in the context of the geographical and geological environment and all available reference events, and to initiate discrimination processing. This is accomplished with six pulldown menus displayed across the top of the map display window.

The **FILE** menu controls entering of data into the map, the display of new maps, and the creation of new reference regions for defining reference events.

The **EDIT** menu contains options for displaying and clearing great circle paths and ellipses, unselecting events, and editing the contents of reference regions.

The **VIEW** menu controls the display of different map overlays, station locations, and reference regions.

The **EVENTS** menu displays error ellipses and shows great circle paths from the events to all the stations which recorded data from the events.

The **FUNCTIONS** menu makes various computations, including great circle paths and cross-sections.

The **EXECUTE** menu provides the interface to initiate the discrimination process.

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4.2.1 FILE Menu Options

The **FILE** options control the actual data which is displayed on the map, including the type of map projection, the location of the map, and the input of events to be plotted on the map.
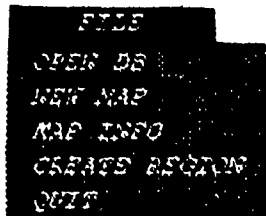
The *OPEN DB* option accesses a database and allows new events to be entered into the bulletin and displayed on the map itself. This option allows other options to be chosen for what data to read in from the database. The *OPEN DB* option is also available in the Top Level Spreadsheet and is discussed in detail in Section 5.4.1.

NEW MAP allows another map to be displayed. When this option is selected, a scrollable list of different maps is displayed. Selecting one of the maps by a mouse click will change the display to the selected map.

MAP INFO provides information about the map itself, including what projection was used and what region the map encompasses.

CREATE REGIONS allows the user to define a region of reference events, or a reference region. Events are selected either from the map or from the bulletin for inclusion in the reference region. A reference region is a rectangular area on the map which encloses all the selected events. The events which are included then become reference events.

QUIT ends the map process and removes the map display from the screen.

4.2.2 EDIT Menu Options

The **EDIT** menu options make changes in objects displayed on the map.

CLEAR GC PATHS removes from the map any great circle paths which have been displayed.

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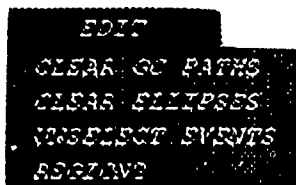
CLEAR ELLIPSES removes from the map any confidence ellipses which have been displayed.

UNSELECT EVENTS unselects any event which has been selected either from the map or the bulletin.

REGIONS allows reference regions to be changed in terms of the events which are included in the reference region. This option displays in the legend window a scrollable window of all region names and four edit options, as shown to the left. When any of the triangles to the left of the region name are moused, the triangle is filled in, the region is displayed on the map, and the events in the region are selected. The edit options are:
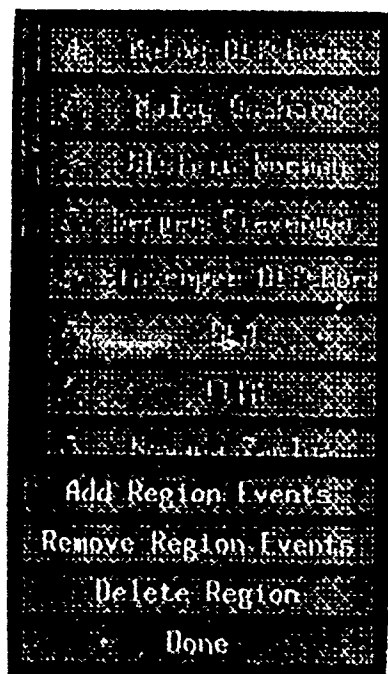
ADD REGION EVENTS adds all selected events to the region and the region coordinates are redefined to include all the events.
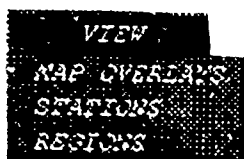
REMOVE REGION EVENTS removes all selected events from the region and the region coordinates are redefined.

DELETE REGION the region is removed from the list.

**DONE** exits the edit region process.

4.2.3 VIEW Menu Options

This menu controls various databases and items which are displayed on the map.

MAP OVERLAYS a second subwindow which allows selection of various databases which can be plotted on the map. These include lat/lon lines, political boundaries, topography, cities, known mine locations, locations of historical PNEs, and historical events from different bulletins.

STATIONS brings up a second subwindow that allows the selection and display of different stations and arrays of stations on the map.
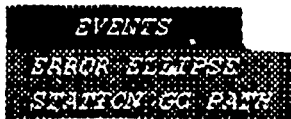
REGIONS brings up a second subwindow, plotted in the legend window, which allows the display of different reference regions on the map, as shown below.
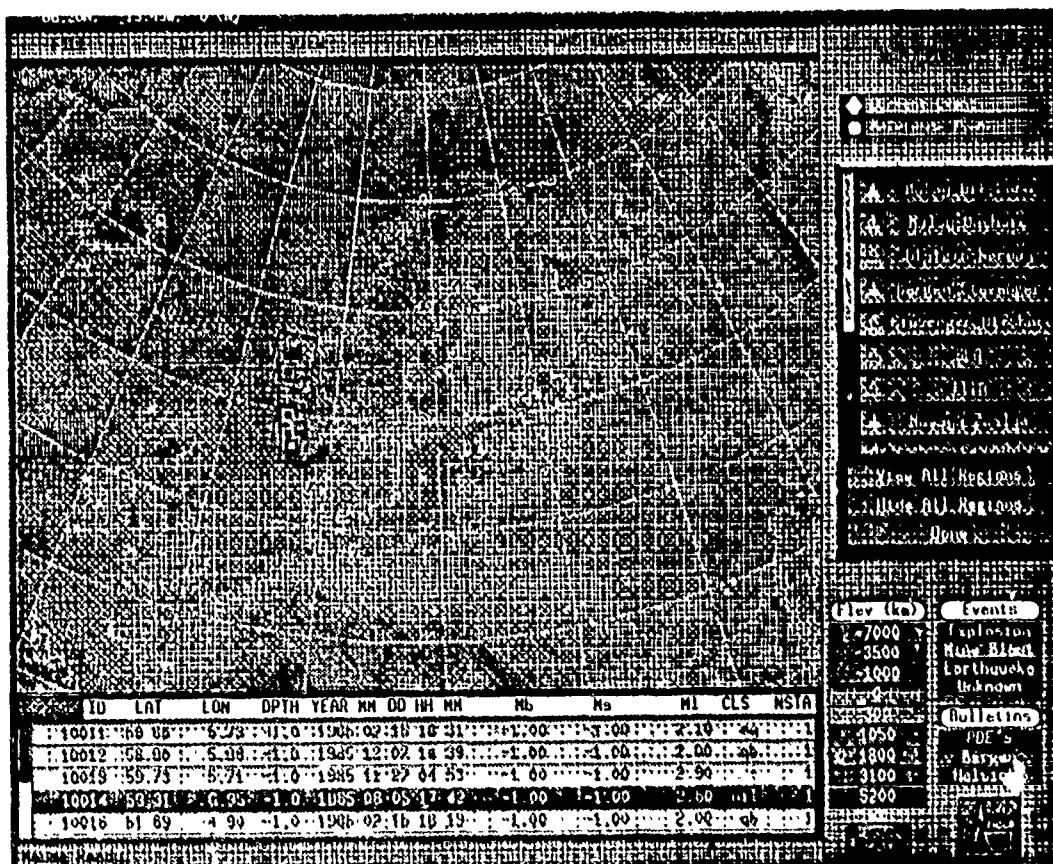
Any region which is selected in the scrollable window is shown in the map. The events contained in the region are selected (highlighted) on the bulletin, assuming they are in the bulletin. *VIEW ALL REGIONS* plots on the map all the regions in the list, *HIDE ALL REGIONS* removes all regions displayed on the map, and *DONE* removes the subwindow and returns control to the menu.

4.2.4 EVENTS Menu Options

This menu allows certain information about the events themselves to be displayed on the map.
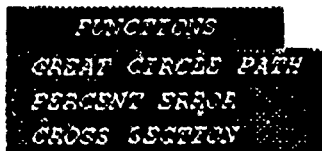
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ERROR ELLIPSE brings up a subwindow that allows the user to select certain events or all events and have their location confidence ellipses plotted on the map.

STATION GC PATH brings up a subwindow that allows the user to select certain events or all events and have the great circle paths from each event location to all recording stations to be plotted on the map.

4.2.5 FUNCTIONS Menu Options

This menu controls various computations, the results of which can be displayed on the map.
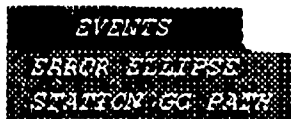
GREAT CIRCLE PATH allows the user to select with the middle mouse button two points on the map, and the great circle path between the two points is computed and plotted on the map. Also, computed distance between the two points is displayed.

PERCENT ERROR computes the percent overlap of a confidence ellipse on land and water. When this option is selected, a subwindow is brought up which allows the user to select a single event or all events.

CROSS SECTION is an option which computes a crustal cross-section between two points on the map. The two points are selected with the middle mouse button and a subwindow is produced with the cross-section, as shown below:
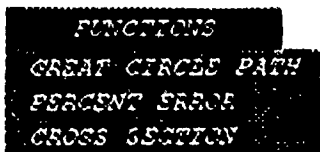
Display 9

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ERROR ELLIPSE brings up a subwindow that allows the user to select certain events or all events and have their location confidence ellipses plotted on the map.

STATION GC PATH brings up a subwindow that allows the user to select certain events or all events and have the great circle paths from each event location to all recording stations to be plotted on the map.

4.2.5 FUNCTIONS Menu Options

This menu controls various computations, the results of which can be displayed on the map.

GREAT CIRCLE PATH allows the user to select with the middle mouse button two points on the map, and the great circle path between the two points is computed and plotted on the map. Also, computed distance between the two points is displayed.

PERCENT ERROR computes the percent overlap of a confidence ellipse on land and water. When this option is selected, a subwindow is brought up which allows the user to select a single event or all events.

CROSS SECTION is an option which computes a crustal cross-section between two points on the map. The two points are selected with the middle mouse button and a subwindow is produced with the cross-section, as shown below:

Display 9

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5.0 TOP LEVEL SPREADSHEET DISPLAY PROCESS

The Top Level Spreadsheet Display process serves both as a top and intermediate level explanation facility and as an interface to bottom level signal-analysis functions. Information about specific discriminants applied to specific events are displayed as alphanumerics and colors directly on the Spreadsheet. However, the Spreadsheet also contains menus and activation boxes to initiate other subprocesses which can change the state of the Spreadsheet itself. In this section, the Top Level Spreadsheet Display process is described.

5.1 GENERAL DESCRIPTION

When the Top Level Spreadsheet Display process is begun, the screen which will appear is shown below:

The Spreadsheet Display window consists of a menubar and a set of rectangular cells. The top set of cells below the menubar and to the right of the corner cell, which is labeled *ORID/DATE/TIME,* represents a set of active discriminants which are labeled. Mousing on any of these top horizontal cells with the middle mouse button displays a window containing a text explanation of the discriminant. The vertical set of cells below the corner cell represents a set of events, labeled by their origin id (ORID), date, and the origin time of the event. These events may correspond to the events displayed in the Top Level Map Display if the Spreadsheet was initiated from the *DISCRIMINATE* option of **EXECUTE**. However, these events can also be loaded in directly from the Spreadsheet using the *OPEN DB* option under *FILE*, discussed in Section 5.4.1 Mousing on any of the leftmost vertical cells with the middle mouse button displays a window with information about the source parameters of the event.

Each of the large rectangular cells in a horizontal row of the Spreadsheet corresponds to all the active discriminants which have been, or can be, applied to a particular event, described by the left-most cell. Each vertical column of cells corresponds to a particular discriminant which has been, or can be, applied to any of the events in the spreadsheet. Within each large cell are three smaller boxes which are color coded and in which information is displayed describing the data status and/or event-characterization results for the discriminant applied to the event. These boxes are discussed in detail in Section 5.2.

Only a portion of the Spreadsheet is displayed on the screen at one time. The screen must be scrolled to expose other parts of the Spreadsheet. For this purpose, the Spreadsheet contains two scrollbars, one at the bottom of the screen and one on the rightmost end of the screen. The Spreadsheet can be scrolled up and down, to expose different events for a particular group of discriminants, or right and left, or to expose different discriminants for a particular group of events. Scrolling the spreadsheet is accomplished by using the mouse and the standard X11 window scrolling procedures. It should be noted that the menubar remains stationary during the scrolling process. For example, the display above shows the discriminants called *MAXPS, HF Pn/Lg,* and *HF Pn/Lg* exposed for the events designated with orids 10011, 10012, 10013, and 10016.

Scrolling the Spreadsheet to the left, using the bottom scrollbar, produces the display below:

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Now, the Spreadsheet shows the cells for three more discriminants, called *Ripple Fire*, *Ms-mb*, *Depth*, and part of *Combined ID*. Further scrolling to the left will expose the rest of the *Combined ID* cell. Note that the menubar and the leftmost set of cells, labeled for the same events, remains the same. The *Combined ID* cell, which presents the overall results of all the discriminants applied to the event, is always present and indicates the rightmost extent of the Spreadsheet.

If the Spreadsheet is scrolled vertically, different events will be exposed for the same set of discriminants. Thus, the menubar and the topmost cells, indicating the discriminants, will remain the same in a vertical scroll, but different leftmost cells will be exposed along with the status/result cells across the horizontal rows.

5.2 SPREADSHEET CELL DESCRIPTION

As discussed above, each large cell represents the application of a single discriminant, represented by the vertical column, to a single event, represented by the horizontal row. Each of the large cells contains three boxes and alphanumeric information, as shown below:

The leftmost box, *STATUS*, has information about the database status. The concept of data status was explained in Section 2.3.1. This box will be filled in with a color, which indicates one of the following status conditions:

Complete (Green)	All the necessary and sufficient conditions are satisfied to run this discriminant on this event.
Incomplete (Yellow)	Necessary conditions are satisfied but not sufficient conditions. The discriminant can be run, but the results might be suspect.
No-Data (Red)	Neither the necessary nor sufficient conditions are satisfied. The discriminant cannot be run for this event.
Neutral (White)	The data status for this discriminant has not been assessed for this event.

The center box, *MODEL*, has information about the results of model-based event characterization. As explained in Section 2.3.1, model-based characterization tries to actually identify the source type. This box will be filled in with a color, which indicates the following results for model-based event identification:

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Earthquake (Green)	This discriminant identifies this event as "earthquake" source type.
Explosion (Red)	This discriminant identifies this event as "generic explosion" (i.e., no distinction is made between the explosion being a mine blast, underwater blast, or nuclear explosion).
Economic Blast (Orange)	This discriminant identifies this event as "economic explosion."
Unidentified (Yellow)	The discriminant could not identify the event.
Neutral (White)	Either the discriminant has not been executed or no model-based rules have been implemented.

In addition to the color, two numbers, separated by a slash, are printed below the box. The number to the left of the slash is the **confidence** of the characterization and the number to the right of the slash is the **relative weight** of the discriminant when the *Combined ID* is applied. The confidence ranges from 0.0 to 1.0, where 1.0 is the highest confidence possible. The relative weight also scales between 0.0 and 1.0 and is determined from the relative size of the absolute weight for the discriminant, defined in the CLIPS rules, to the absolute sizes of all the other discriminant weights applied to the event. This number is set when the *Combined ID* discriminant is applied, otherwise, it will be set to zero. The relative weight is multiplied by the confidence when the overall confidence of all the discriminant is computed by the *Combined ID* process.

The rightmost box, *CASE,* gives the information about the results of case-based event characterization. As explained in Section 2.3.1, case-based event characterization determines how similar the event is to reference events in nearby reference regions. This box will be filled in with a color, which indicates one of the following results:

Similar (Green)	The discriminant features for this event are similar to reference events in the nearest reference region.

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Dissimilar (Red)	The discriminant features for this event are dissimilar to reference events in the nearest reference region.
Unknown (Yellow)	It cannot be determined if the discriminant features for this event are similar or dissimilar to reference events in the nearest reference region.
Neutral (White)	Either the discriminant has not been executed or no case-based rules have been implemented.

As in the case of model-based characterization, two numbers are printed beneath the *CASE* box which denote the confidence and relative weight of the discriminant for case-based characterization.

In addition to the color coding on the boxes, the model-based and case-based characterization of the event are written out above the three boxes on the left and right sides, respectively, of a slash.

Note: The methodologies of how these discriminants are applied, how the event characterizations are made, and how confidences and weights are applied can be found in the CLIPS rules. There is currently no systematic procedure for how this should be done for all discriminants and, therefore, the methodologies are very ad hoc and vary from discriminant to discriminant. Details about the current set of rules are given in the appendix of this document. It is expected that these rules and discriminants will be changed or deleted and new ones added as a result of future research.

5.3 VIEWING RESULTS SUMMARIES

In addition to providing the Top Level summary results, described above, the different boxes are mouse sensitive. When they are moused, subwindows will be produced which present result summaries. Result summaries will be produced whenever the color of the box is any color besides white. The results summary windows give text explanations about the results of the

processing, as well as additional buttons for accessing Bottom Level Signal Analysis functions. The processes which control results summaries are called Intermediate Level Discriminant Processes and are discussed in more detail in Section 6.0.

5.4   MENUS

The menus on the Top Level Spreadsheet allow the user to control what data and how that data is displayed in the spreadsheet and to interactively execute different discrimination processes. This is accomplished by six pulldown menus displayed across the top of the Spreadsheet Display window.

The **FILE** menu controls what data and discriminants are displayed in the Spreadsheet.

The **EDIT** menu has edit functions for the Spreadsheet.

The **VIEW** menu has options controlling how the events are displayed in the Spreadsheet.

The **EXECUTE** menu has options which control the actual assessment of data status and the execution of discriminants.

The **FUNCTION** menu has options for executing bottom level signal analysis functions on selected events. These functions can also be invoked from results displays in the Spreadsheet.

5.4.1   FILE Menu Options

The **FILE** options control the actual data and discriminants which are displayed on the Spreadsheet .
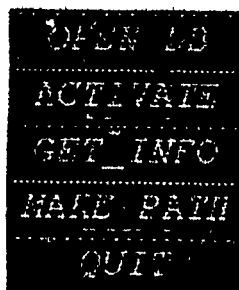
The **OPEN DB** option executes the ISEIS Database Query Editor process to access the database and allow new events to be entered into the Spreadsheet. When this option is selected, the subwindow shown below is displayed:

This window consists of a number of check boxes on the left and data entry boxes on the right. The different entries are :

Enter User name   The database name, password, and host is entered in this line.

Current Data   If this box is checked, only current events (i.e., non-reference events) are read in.

Reference Data   If this box is checked, only reference events are read in.

SINGLE ORID   When this box is checked, only a single origin id is read in. The origin id is then entered in the box to the right.

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ORID RANGE	When this box is checked, all origin ids between the **FROM** entry to the **TO** entry are read in.
TIME	When this box is checked, all events with origin times between the **FROM** entry to the **TO** entry are read in.
SINCE	When this box is checked, all events with origin times after the time entered in the **SINCE** entry are read in.

Note: All times must be entered in with the exact format ddmmmyyyy (day/month/year) followed by a space and then hh:mm (hour minutes).

YESTERDAY	When this box is checked, all events since the previous day are read in.
TODAY	When this box is checked, all events on the current day are read in.
LOCATION	When this box is checked, all event between the the **FROM** and **TO** latitude and longitude range are read in.
RANGE FROM SENSOR	Only events at a specified distance in km from a specified event are read in.
REFERENCE REGION	When this box checked, all reference events in a specified reference region are read in.
DEPTH	When this box is checked, all events with depths between the **FROM** depth entry to the **TO** depth entry are read in from the database.

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MAGNITUDE   When this box is checked, all events with magnitudes between the **FROM** magnitude to the **TO** magnitude entry are read in from the database.
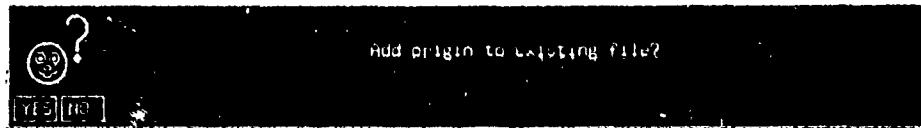
DONE   When this button is pressed with the mouse, the ISEIS Database Query Editor process accesses the events from the database which satisfy the criteria specified in the form.

CANCEL   Pressing this button cancels the process and returns control to the Spreadsheet display.

If the done button is pressed, the following dialog box is displayed:

If the **YES** button is pressed, the events accessed by this process will be added to those currently in the Spreadsheet. If **NO** is pressed, the old events in the Spreadsheet are deleted before adding the new ones.

The *ACTIVATE* option under the **FILE** menu allows the user to control which discriminants will be applied to the events in the Spreadsheet. When this option is selected, the following subwindow is displayed:

```
┌──────────────────────────────────────────────┐
│  ■      MAX P/S          │   CLEAR             │
│  ■      HF Pn/Sn         │  SELECT ALL         │
│  ■      HF Pn/Lg         │   DEFAULT           │
│  ■ LG SPECTRAL RATIO     │    DONE             │
│  ■        DTW            │                     │
│  ■    Ripple/Fire        │                     │
│  ■       Ms-Mb           │                     │
│  ■       Depth           │                     │
│  ■    Combined ID        │                     │
└──────────────────────────────────────────────┘
```

The check boxes which are filled in white indicate which discriminants are "active " i.e.,
are included in the Spreadsheet The user can then mouse on the boxes for the discriminants to
delete from the Spreadsheet. The **CLEAR** button "de-activates" all the discriminants. **SELECT
ALL** "activates" all discriminants. **DEFAULT** activates those discriminants which were "active"
when the Spreadsheet was initiated. The **DONE** button returns control to the Spreadsheet display
with only the active discriminants included.

GET INFO option under **FILE** provides information about the Spreadsheet.

MAKE PATH is an option for entering path correction information into the database.
Path corrections are estimates of anelastic attenuation for different phases which are currently being
used by the spectral-ratio discriminant. Selection of this option displays the following subwindow.

```
.: KE PATH ENTRY

   .:ELECT REGION              SELECT STATION      SELECT PHASE

          •     BLA                APA                 Pn

          Bergen_Stavenger        ARS                 Pg

              E4                   ARS                 Sn

              E8                   BOD                 Lg        r

          Kola_Peninsula          NOR                 P   ?

          Kola_Capelyarnyi        NRI                 S

          Leningrad_Region        NRS

                                  NRS
    .o:      0.00        Defau    NVS        •
    .ta:    0.00
                         Enter    OBN
    fo:     0.00
    gvel:   0.00         Done     TLY        ►
```

This window has four windows for entering path corrections for a phase recorded at a
station from a reference region. The **SELECT REGION** window is a scrollable set of check
boxes where the user selects the reference region. The **SELECT STATION** window has a set
of check boxes for stations which the user selects for path corrections relative to the specified
reference region. The **SELECT PHASE** window contains check boxes where the user selects
the phases for which path corrections are to be entered. After the reference region, station, and
phase have been selected, the frequency-dependent anelastic attenuation values of Qo, $zeta$, fo, and
$gvel$ are typed into the box. Qo is the anelastic attenuation factor at base frequency fo, $zeta$ is the
power of frequency, and $gvel$ is the group velocity of the phase in km/sec. If the **Default** button
is pressed, a set of default values are entered. When the **Enter** button is pressed, the path
correction values are entered into the database. The user can enter as many different corrections as
desired. When **Done** is pressed, control is returned to the Spreadsheet.

QUIT under the **FILE** menu terminates the Spreadsheet process

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5.4.2 EDIT Menu Options

The **EDIT** menu options make changes in the data displayed in the Spreadsheet and make new discriminants by copying old ones.
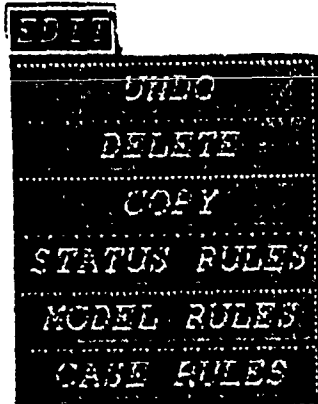
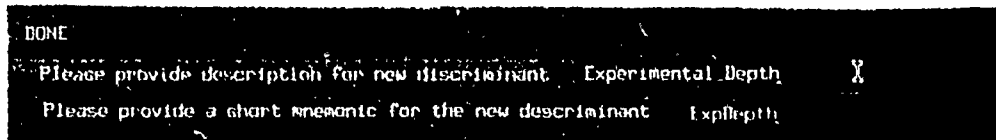*DELETE* removes a selected row or column from the Spreadsheet.

UNDO essentially returns the Spreadsheet back to the state it was initially.

COPY is used to make another discriminant which is a copy of an existing one in the Spreadsheet. This function is useful if the user wishes to make a new discriminant which is only slightly different than an existing one, such as being applied to a different phase or having different parameters. An example might be to make a copy of the discriminant, *SRLG*, which is spectral ratio for *Lg*, but define it for another phase, such as *Pn*. The *COPY* function duplicates all the software for accessing the database and rules, gives the duplicate a new name, and places it in the Spreadsheet under the new name. It is up to the user to edit the rules to make it distinct from the old discriminant. When invoked, *COPY* displays the following subwindow:

```
     Please select descriminant to be copied        DONE

 Depth_Teleseismic_Id                                CANCEL
 Dynamic_Time_Warping
 High_Frequency_Pn/Lg
 High_Frequency_Pn/Sn
 Intelligent_Combined_Id
 Max_P/S_Ratio
 Ms-Mb_Teleseismic_Id
 RippleFire
 SRLG.
```
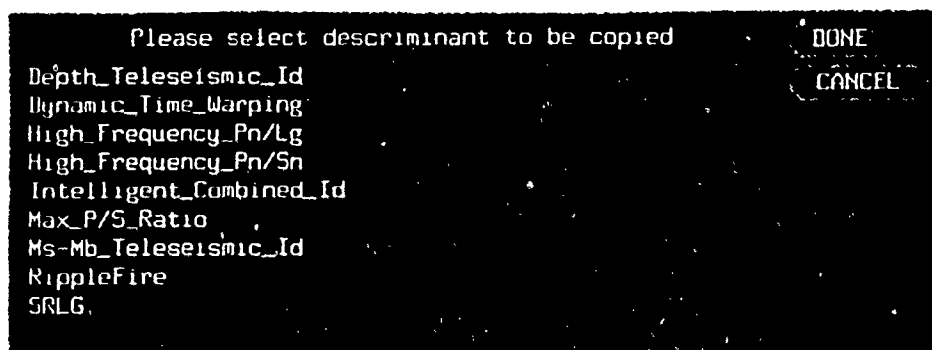
The window shows a list of discriminants currently existing in the Spreadsheet. The user may select the one to duplicate by mousing on the discriminant name and mousing on the *DONE*

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button. The *CANCEL* button quits the process with no duplication. After selecting *DONE*, a second subwindow is displayed.

The discriminant is copied and assigned as name (mnemonic) which is entered into this window. When the *DONE* button is pressed in this window, the discriminant copy is placed into the Spreadsheet.

The next three options under **EDIT**, *STATUS RULES*, *MODEL RULES*, and *CASE RULES* allow the analyst to view the CLIPS rules for a discriminant and to make changes in the rules, if desired. Rule edit capability is also provided in each of the Intermediate Level Summary Displays, described in Section 6.0, although these edit functions can only be accessed after a discriminant has assessed, in the case of status rules, and executed, in the case of model and case rules. The options under the **EDIT** menu allow these rules to be edited without having to assess or execute discriminants.

STATUS RULES brings up a standard XEDIT window containing the status CLIPS rules for a discriminant. The discriminant must first be selected from the first row of cells in the Spreadsheet before *STATUS RULES* is selected.

MODEL RULES and *CASE RULES* provides the same edit window for model and case rules as it does for the status rules. An example of the window for the *HF Pn/Sn* model-based discriminant rules, is shown below:

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The rules can then be changed by using editing procedures for XEDIT and then mousing on the **SAVE** button at the bottom of the window. The edit session can be ended by mousing on the **QUIT** button.

Note: These edit functions should only be used by a user familiar with the rules and CLIPS, since they can make permanent changes in the rules. Also, only minor changes in existing or copied rules should be made with these functions. The writing and debugging of entirely new CLIPS rules should usually be done offline.

5.4.3 VIEW Menu Options

The **VIEW** menu options control the order in which events are displayed in the Spreadsheet and provide user help text for functions in the Spreadsheet.
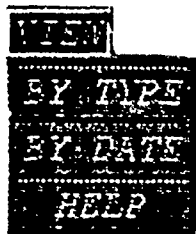
BY DATE displays the events in the Spreadsheet in order of date.

BY TYPE displays the events in order of type (i.e., earthquake, explosion, mine blast). This option has not yet been implemented.

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HELP displays the following subwindow:

```
<< DISCRIMINATE MENU BAR HELP >>

FILE EDIT VIEW EXECUTE PROCESS

    Welcome to online menubar help!  To obtain help dialo
    spreadsheet menu bar items and options, simply select the des
    in the menubar.  The Menubar is used along with the spreadshe
    to accomplish various tasks.  In general, a user mouses on in
    Spreadsheet cells and then he chooses a menu option from the
    may also choose groups of cells by mousing on Event buttons o
    buttons.  Actively selected cells will be highlighted in RED.
    menubar options require that ONLY one Spreadsheet cell be sel
    menubar option selection.  Other options allow multiple selec
    The Event buttons are located to the extreme left of the disp
    discriminant buttons are located just underneath the menubar.
    these buttons with the MIDDLE mouse button for help dialogs.
    Help dialogs pertaining to command buttons can be obtained by
    with the MIDDLE mouse button.

DONE
```

The ***HELP*** subwindow provides a menubar which is the same as that in the Spreadsheet.
When any option under any of the menus is selected, another subwindow is displayed containing a
text explanation. The following help display is produced when the ***OPEN DB*** under the **FILE**
menu is selected:

```
<< USER HELP >> << Help For Option: OPEN DB Under: FILE >>
    This Menubar option is used for loading new events into the Spreadsheet
    display.  The Spreadsheet displays a form which allows the user to specify
    events for retrieval from a database.  The user can select events by specifying
    an individual event ID or event ID range, event arrival times and ranges and or
    other event selection criteria.  If events are found, the user is asked
    whether he wishes to add the events to the event file.  A yes selection
    results in the merging of the newly selected events with the previous events.
    A NO selection removes the old events and replaces them with the new event
    selections.  The Spreadsheet will redisplay the new events in either case.
DONE
```

5.4.4 EXECUTE Menu Options

The **EXECUTE** menu is the most important one in the Spreadsheet. It contains all the
options that allow the user to control all discriminant processing for events in the database.

In order to understand how these options work, it is necessary to understand how event-discriminant cells are "selected." A cell may be selected by simply mousing on the desired cell and the selected cell in the Spreadsheet is then outlined in red, as shown below:


Only the one cell is selected. Mousing again on the cell deselects the cell. All the cells for a single discriminant can be selected by mousing on the discriminant cell and an entire column is then outlined in red, as shown below:

The column cas... ... ... the comparison cell. Individual cells in the column ... ... the row cells are then outlined ... ...

Selection and deselection are used to assign particular discriminants to be applied to specific events. The options under EXECUTE control these selection, deselection, and discriminant application procedures.
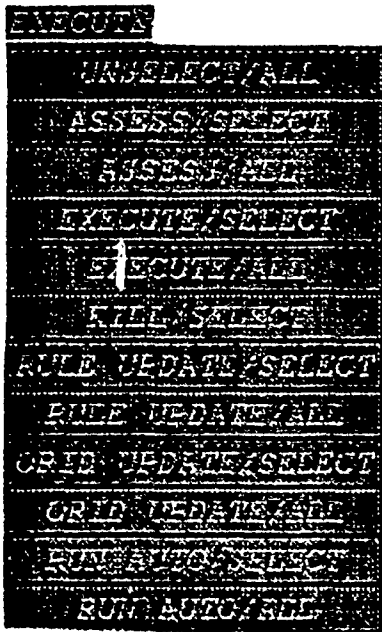
UNSELECT / ALL deselects any cells which are currently selected. This function is useful for making sure that all cells have been deselected on the Spreadsheet, including those which have been scrolled off the visible part of the Spreadsheet.

ASSESS / SELECT assesses the data status for all cells which have been selected, corresponding to specific discriminants applied to specific events.

ASSESS / ALL assesses all discriminants for all events on the Spreadsheet, regardless of what selections have been made.

When either *ASSESS/SELECT* or *ASSESS/ALL* are executed, one or more processes are initiated to apply the data status rules for selected or all discriminants applied to selected or all events. When the assess functions begin, the Status box on the cell, for a discriminant/event pair selected for assessment, is filled in with blue and the letter "A" appears below the box, as shown below, where the *HF Pn/Sn* discriminant is being assessed for orids 10012 and 10013:

When the letter "A" appears, the cell is not selectable until the assessment has completed. When the assess function has completed, the "A" letter disappears, and the Status box is filled in with the appropriate color (red, yellow, or green) for the result of the status assessment. Then, the status box becomes mouse sensitive. When the status box is moused, a sub window is displayed which contains text describing the status of the discriminant applied to the event.

EXECUTE / SELECT executes selected discriminants on selected events.

EXECUTE / ALL executes all discriminants on all events in the Spreadsheet, regardless of what selections have been made.

When a discriminant is executed the Status box is cleared, it will blink, and the letter "E" appears below the Status box. It indicates that the discriminant is executed. When the execution has completed, the discriminant value appears and the Status boxes are

colored in with an event characterization color code, as shown below, where the *HF Pn/Sn* discriminant is being executed for orids 10012 and 10013.

When the execute function has completed, the "E" letter disappears, and the Model and/or Case boxes are filled in with the appropriate color (red, yellow, or green) for the results of event characterization. If the Model or Case boxes are colored in, then they are mouse-sensitive and will display subwindows with text describing the results of the event characterization based on the discriminant corresponding to the column in the Spreadsheet.

Note: Discriminant execution may consist of a combination of signal analysis and the execution of CLIPS rules. Also, ISEIS will not permit discriminants to be executed unless the discriminant status has been assessed to be complete or incomplete. Attempts to execute discriminants which have not been assessed (white status box) or have no-data status (red status box) will result in the display of an error dialog box.

KILL / SELECT interrupts the execution of a discriminant which is selected.

RULE UPDATE / SELECT runs only the CLIPS rules on a selected discriminant for a selected event and not the signal processing, if additional signal processing is actually part of the discriminant cycle.

RULE UPDATE / ALL runs only the CLIPS rules on all the discriminants on all the events in the Spreadsheet, regardless of what is selected.

ORID UPDATE / SELECT updates the database with the event identification for selected events to be that determined by the *Combined ID* discriminant. Henceforth, the event will be displayed with this identification on the map display.

ORID UPDATE / ALL updates the database with the *Combined ID* event identification for all events in the Spreadsheet.

RUN AUTO / SELECT runs the automatic discrimination function on the all the discriminants for selected events in the Spreadsheet. This function automatically performs all signal analysis required for status assessment and discriminant execution.

RUN AUTO / ALL runs the automatic discrimination on all the events and discriminants displayed in the Spreadsheet.

Note: The ASSESS and EXECUTE functions both assume that certain prerequisite signal analyses, most importantly, incoherent beam analysis (IBEAM) and spectral analysis, has been applied to all waveforms and that phases have been selected on the incoherent beams. These must be accomplished by interactively using the Bottom Level Signal Analysis functions, which are described in Section 7.0. The automatic discrimination function, invoked with the RUN *AUTO/SELECT* or RUN *AUTO/ALL*, attempts to do all these functions automatically, assuming that phase identifications have been made and stored in the database in the Analyst Review Station of the IMS.

5.4.5 PROCESS Menu Options

The **PROCESS** menu allows the user to access the Bottom Level Signal Analysis and Display functions for processing waveforms, extracting features, and viewing plots of features. An event to be processed must be selected from the Spreadsheet before selecting a process from this menu. Each of the processes in this menu have their own graphics interfaces that are displayed on top of the Spreadsheet or on another screen, depending on how the processes are allocated. (See the ISEIS Maintenance Manual for how to allocate processes.)
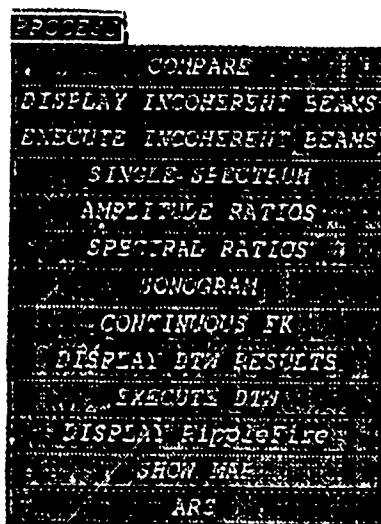
COMPARE is a function for displaying and overlaying waveforms for the current event and other events in the Spreadsheet. This function is described in detail in Section 7.4.3.

DISPLAY INCOHERENT BEAM allows the user to view all incoherent beams computed for the selected event. This function is described in detail in Section 7.2.1.

EXECUTE INCOHERENT BEAM allows the user to interactively setup and run the process to compute incoherent beams for the selected event. This function is described in detail in Section 7.2.1.

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SINGLE SPECTRUM allows the user to interactively setup and run the process to compute spectra for individual time intervals for the selected event. This function is described in detail in Section 7.2.2.

AMPLITUDE RATIOS allows the user to compute amplitude ratios between different regional phases for the selected event and to compare the values with reference events. This function is described in detail in Section 7.3.1.

SPECTRAL RATIOS allows the user to compute spectral ratios for different regional phases for the selected event and to compare the values with reference events. This function is described in detail in Section 7.3.2.

SONOGRAM allows the user to interactively setup, run, and display the sonogram process for the selected event. This function is described in detail in Section 7.4.1.

CONTINUOUS FK allows the user to interactively setup, run, and display the continuous FK process for the selected event. This function is described in detail in Section 7.4.2.

DISPLAY DTW RESULTS provides the user with a graphics interface to view the results of dynamic time warping processing of the selected event. Details about the DTW process are given in Section 7.3.4.

EXECUTE DTW allows the user to setup and run the process for dynamic time warping for the selected event. Details about the DTW process are given in Section 7.3.4.

DISPLAY RIPPLE-FIRE allows the user to review the results of the MERSY process for the identification of ripple-fired events. Details about this process are given in Section 7.3.3.

SHOW MAP initiates the map process. The events displayed on the Spreadsheet are transferred to the map and displayed. The Map Display process is described in Section 4.0.

6.0 INTERMEDIATE LEVEL DISPLAY PROCESS

The Intermediate Level Display process controls the display of the results summaries, which are displayed when the user mouses on Status, Model, or Case boxes within any of the Spreadsheet cells. These intermediate level displays are available whenever the boxes are filled in with a color. In addition to the textual explanations of the data status and event characterization results, these displays allow to user to view the CLIPS rules themselves and the tracebacks of the rule execution. The rules can also be edited in this interface.

6.1 DATA STATUS SUMMARY DISPLAY

When the data status box in any cell has been filled in with a color (red, green, or yellow), a subwindow will be displayed, when the box is moused, which will give a summary explanation of the status. An example for such a summary display for the discriminant *MaxPS* for the event with orid 10013 is shown below:

The main part of the subwindow contains a text explanation of the data status for the discriminant. This explanation states what data is available, and if the status is not *complete*, the missing data and how it can be acquired is explained.

At the bottom of the Data Status Results window are a set of buttons. These buttons, when moused, provide more information about the reasoning process which produces the status assessment and interface to signal analysis functions which can be used to upgrade the data status.

The *DRIBBLE* button in the Data Status Results window produces another scrollable window which shows the contents of a "dribble" file, produced by CLIPS, which contains a detailed trace of the assertions and rules invoked that led to the status assessment, as shown below:

More of the trace can be viewed by scrolling the window down. When the *QUIT* button in the Dribble History Summary window is pressed with the mouse, the window is removed.

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Pressing the **RULES** button in the Data Status Results window produces an edit window containing the data status rules, which were executed to produce the explanation, as shown below:

```
                    MaxPS DATA STATUS Rules Summary For Orid: 10013

;;;;;  Max P/S Rules  - Status ;;;;;

;;; Abstract  Status rules for Max P/S ratio discriminant

;;; These rules examine all P and S wave types associated with an
;;; event and  tries to identify the event based relative excitation
;;; of the maximum compressional and shear energy. Earthquakes are.
;;; presumed to have more shear wave energy relative to compressional
;;; wave energy than explosions.

;;; The status rules require that some P and S wave phases exist

;;; Author:      Doug Baumgardt (ENSCO)

;;; Input:       Input assertions file .

;;; Output:      Statement of status
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
(defrule dump
  (declare (salience 1000))
=>
  (watch all))

;;; Explanation-open opens the data file where the explanation results
;;; will go.

(defrule explanation-open
  (declare (salience 100))
  (initial-fact)
  (discriminant ?orid ?techname ?dir)
```

QUIT SAVE

This window displays the contents of the CLIPS rule file located on disk in a standard XEDIT window contained in the X11 package. The rules can be changed by using the editing features of XEDIT, described in the X11 documentation. After making the changes, mousing on *SAVE* makes the changes to the rules in the file. Mousing on *QUIT* removes the window and returns user control to the Data Status Summary window. Mousing on *QUIT* before mousing on *SAVE* after changes have been made to the rules will not save the changes in the rule file.

Note: If changes are made to the rules, they must be reassessed by using the *ASSESS* options in the **EXECUTE** menu of the Spreadsheet before the changes are reflected in the status assessments or the Status Result Summary. Thus, all events will have to be reassessed before the rule changes are applied.

The other boxes at the bottom of the window provide interfaces to signal analysis functions which can be used to upgrade the status of the discriminant for the event, assuming that the status was *Incomplete* or *No Data*. They are specialized for each discriminant and are also accessible through the **PROCESS** menu of the Spreadsheet. Mousing these buttons will initiate one of the signal analysis functions, which will bring up additional subwindows either on top of the Spreadsheet or on another machine to which the process has been allocated. Section 7.0 discusses these functions in more detail.

6.2 EVENT CHARACTERIZATION SUMMARY DISPLAY

If the Model or Case button is moused after it has been filled in with a color (red, green, yellow, or orange), it will bring up a subwindow containing an explanation of the characterization of the event using case and/or model based reasoning. The example of the Model-Based Results window for the *MaxPS* discriminant applied to an event is shown below.

.•,
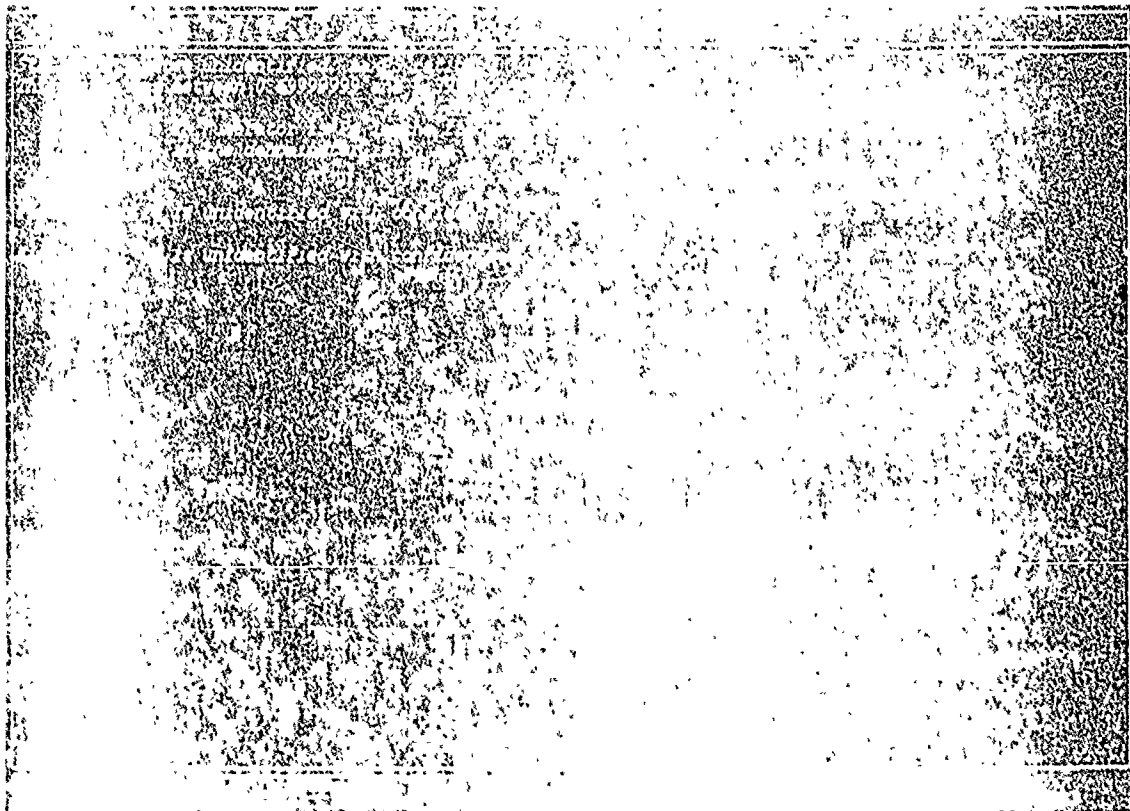
```
             MaxPS MODEL BASED Dribble History Summary For Orid  10013

FIRE   2 explanation-open: f-0,f-1
==> f-7      (path-name "/1se1s/data/explanations/MaxPS/10013.MDL")
==> f-8      (output-files open)
FIRE   3 init-params: f-0
==> f-9      (params 0.25 0.5 0.69999999 1.39999998 2)
FIRE   4 init-vgt: f-0
==> f-10     (abs-vgt 5)
FIRE   5 init-unidentified: f-0
==> f-11     (unidentified 0 0.5)
FIRE   6 init-max: f-6,
==> f-12     (maximum-amplitude 0 P 0 0 0 NRS)
<== Activation 0      init-max: f-5,
<== Activation 0      init-max: f-4,
<== Activation 0      init-max: f-3,
==> Activation 0      get-max-p: f-5,f-12
==> Activation 0      get-max-p: f-4,f-12
==> f-13     (maximum-amplitude 0 S 0 0 0 NRS)
==> Activation 0      get-max-s: f-13,f-6
==> Activation 0      get-max-s: f-13,f-3
FIRE   7 get-max-s: f-13,f-3
==> f-14     (maximum-amplitude 2.61999989 S Lg 0.5 2.5 NRS)
==> Activation 0      remove-amp-s  f-14,f-3
==> Activation 0      get-max-s: f-14,f-6
<== f-13     (maximum-amplitude 0 S 0 0 0 NRS)
<== Activation 0      get-max-s: f-13,f-6
<== f-3      (phase-type (name Lg) (amp-rms 0.59799999) (amp-max 2.61999989) (freq-high 2.5) (fr
<== Activation 0      remove-amp-s: f-14,f-3
FIRE   8 get-max-s: f-14,f-6
==> f-15     (maximum-amplitude 2.66899991 S Sn 0.5 2.5 NRS)
==> Activation 0      remove-amp-s  f-15,f-6
<== f-14     (maximum-amplitude 2.61999989 S Lg 0.5 2.5 NRS)
<== f-6      (phase-type (name Sn) (amp-rms 0.616) (amp-max 2.66899991) (freq-high 2.5) (freq-lo
```

Scrolling the window down provides more of the trace.

Mousing on the **RULES** button of the Model- or Case-Based Results window produces
an edit window containing the rules used in the event characterization, as shown below for model-
based event identification using the *MaxPS* discriminant:

Max P/S Rules - Discriminate

Abstract: Status rules for Max P/S ratio discriminant

These rules examine all P and S wave types associated with an event, and tries to identify the event based relative excitation of the maximum compressional and shear energy. Earthquakes are presumed to have more shear wave energy relative to compressional wave energy than explosions. The discriminant consists of first finding the maximum P and S amplitude, irregardless of frequency, and then forming ratios of the max amplitudes. Then, the ratios are compared to expected thresholds and the event is identified, with an associated confidence.

The status rules require that some P and S wave phases exist.

Author: Doug Baumgardt (ENSCO)
Input: Input assertions file
Output: Statement of status

```
(defrule duno
  (declare (salience 1000))
  (initial fact)

(watch all))

Explanation open opens the data file where the explanation results
will go.
```

QUIT SAVE

As in the case of the status rules discussed above, this window displays the contents of the CLIPS rule file located on disk in a standard XEDIT window contained in the X package. The rule can be changed by using the usual features of XEDit described in the Software documentation. After making the changes, mousing on **SAVE** makes the changes to the rules in effect. Mousing on *QUIT* removes the window and returns user control to the Model Based or Case Based Results window.

Note: If changes are made to the discriminant rule files, they must be re-run using the *EXECUTE* or *RULE UPDATE* option on the EXECUTE ... menu ... S... before the ... rules and updated ... S... events will ... ...

As in the case of the Data Status Summary display window, the Model Based and Case-Based Results window have additional buttons at the bottom of the window which can be moused to interface various signal analysis functions which relate to the discriminant applied to the event. These functions allow the user to analyze the discrimination feature results in more detail. Each of these processes bring up additional subwindows, either on top of the Spreadsheet or on another machine to which the process has been allocated. Section 7.0 discusses these functions in more detail.

6.3 COMBINED ID SUMMARY DISPLAY

Combined ID is a process which is run after a set of individual discriminants have been applied to an event in the Spreadsheet. *Combined ID* is applied in the same way as individual discriminants and is always present in the Spreadsheet. Data Status assessment for *Combined ID* determines whether or not the requisite number of discriminants has been applied to the event. This number currently is set by assertions in the CLIPS data status rules for *Combined ID*. When the status is *complete* for *Combined ID*, the results of the discriminants which have been applied to the event are combined, both for model-based and case-based identification, to provide an overall characterization of the event.

When the Status button is moused for *Combined ID*, a Data Status Summary window, like that for all other discriminants, is displayed. If the Model or Case buttons are moused, after the Status has been assessed as *complete*, a set of color bars is displayed, like that shown below:
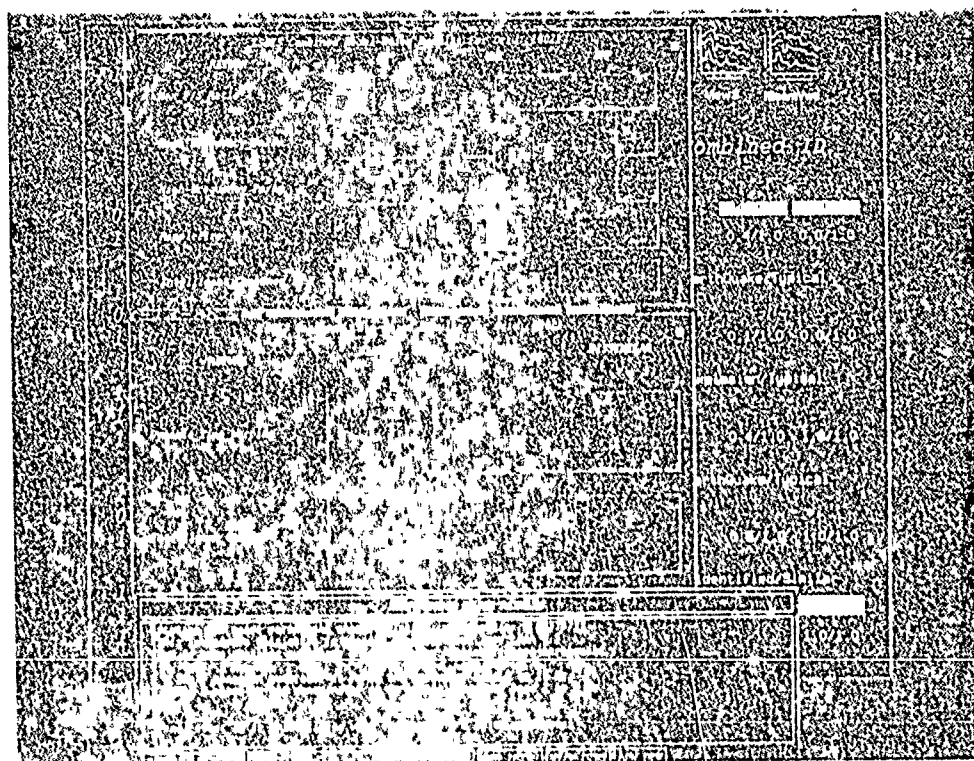
The d... ...For the model-based results, the colored
part of the re... ...confidence... d Q... If the event is
unidentified... ...confidence in the EX and EQ
directions... ...of the identification. The bars
are colo... ...for each quakes, red for
generic expo... ...unidentified. For case-based
results, the colo... ...for the... ar, and the
length of t... ...according to the code
used in... ...known. A bar
labeled h... ...the overall
continued

...ed, the
Results S... *RETURN*
button is...

7.0 BOTTOM LEVEL DATA ANALYSIS AND DISPLAY FUNCTIONS

This section discusses the Bottom Level Data Analysis and Display functions of ISEIS.

7.1 GENERAL DESCRIPTION

These processes support the signal analyses required for the execution of the discriminants. The display functions allow discriminant features of an event to be examined in detail in comparison with those for reference events. In addition to providing feature data for discriminants, these functions can be used for interactive event analysis and discrimination research.

These functions all support the analysis of a single event, called the **current event**, which is selected from the Spreadsheet. Feature data from other events, called **reference events**, can be compared with that of the current event in a manner analogous to case-based event characterization. Reference events are user-selectable and are organized according to the reference regions to which they are assigned.

There are four categories of processing functions at this level:

1) Support signal analysis functions - These are functions which provide the necessary signal processing needed for the generation of discrimination features. Examples include single spectrum and incoherent beam computation.

2) Standard discrimination functions - These do the actual signal feature extraction needed for discriminants. Examples of such functions include phase amplitude ratio computation or spectral ratio computation for a single phase.

3) Discriminant function display processes - These functions provide the displays of the results of processing of the current event compared with those of reference events. In ISEIS, these functions are used in combination with the interactive signal analysis functions in category 2.

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4) Miscellaneous signal analysis and research functions - These are signal analysis functions which are not directly needed for some discriminant but are available to the user for research purposes. A prime example is the continuous spectrum or sonogram function, which makes plots of signal power as a function of frequency and time.

These processes are all applied to a certain seismic event, the current event. They have a common interface, consisting of a top level menubar display with the following standard set of menus:

FILE - all have the quit function which ends the process.

VIEW - view menus provide displays of the signal analysis results.

SELECT - select menus contain options for setting parameters for the signal processing functions.

EXECUTE - execute menus contain the options for starting the process, either as an interactive or background process.

In the remainder of this section, each of the processes under these categories are discussed in detail.

7.2 SUPPORT SIGNAL ANALYSIS FUNCTIONS

The regional discriminants in ISEIS rely extensively on features extracted from incoherent beam envelopes and spectra measured on regional phases. Thus, the two most important support signal analysis functions of ISEIS are IBEAM, for computing incoherent beams, and FSDISPLAY, for the computing spectra, respectively.

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7.2.1 Incoherent Beam Analysis (IBEAM)

IBEAM provides the user interface for setting up the inputs to the process to compute and store incoherent beams, executing the process, and viewing the results. The IBEAM function can also be invoked from the automatic process requiring little or no user interaction.

An incoherent beam is a smoothed envelope of a seismic signal. ISEIS incoherent beams are computed by averaging waveform amplitudes, after the waveforms have been prefiltered, in user specified time windows which are shifted down the traces. For array data, these time-averaged amplitudes are averaged across the elements of an array. For single-channel data, time averages are only made for one channel.

IBEAM has a set of predefined Butterworth recursive filters which are applied to the waveforms prior to computing time and array averages. The preset filters are defined for both 20 Hz and 40 Hz sampled data, although they are not currently the same filters for the two sampling rates.

The IBEAM process computes up to nine time-series, for nine different bandpass filters, that include frequency, computed by counting peaks, average amplitude, average power, log of the average amplitude, log of the root-mean-square (rms) amplitude, and the standard deviations of these four functions. Although all the functions are computed, ISEIS currently only uses one of these, the log-rms amplitude.

Note: Incoherent beamforming, strictly speaking, relates to array processing since the time averages are computed in time windows on each array channel, which in turn are averaged across the array. However, in the ISEIS system, such measurements can also be made from single-channel data and thus, in the single-channel context, the term "incoherent beam" refers to an envelope trace of the single-seismogram component, usually the vertical component.

Two IBEAM interfaces are available to the user, one to view incoherent beams *(VIEW IBEAMS)* and the second to set up and execute the process to compute incoherent beams *(RUN IBEAMS)*. Either of these processes can be run from the Spreadsheet **PROCESS** (see Section

5.4.5) menu or from buttons in the results displays for discriminants (see Section 6.0). Moreover, the *VIEW IBEAM* process can also be run from the *RUN IBEAM* process. Each of these processes is initiated on a single event, selected from the Spreadsheet.

When the IBEAM process is initiated for a selected current event, a subwindow is created containing the IBEAM menubar, which has the standard menus discussed above in Section 7.1.

7.2.1.1 FILE Menu Options
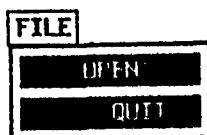
The **FILE** menu currently has only one option, *QUIT*, which exits the IBEAM process and returns control to the spreadsheet. The *OPEN* option, for opening the database to bring in another event, has not been implemented.

7.2.1.2 VIEW Menu Options

The **VIEW** menu allows the user to preview the raw waveforms and to access the function to view previously computed incoherent beams.

If the *VIEW TIME-SERIES* option is selected, the subwindow shown below is displayed:

VIEW TIME SERIES for orid 18
One drag, then press button for Zoom

Event: 18
Station: N25
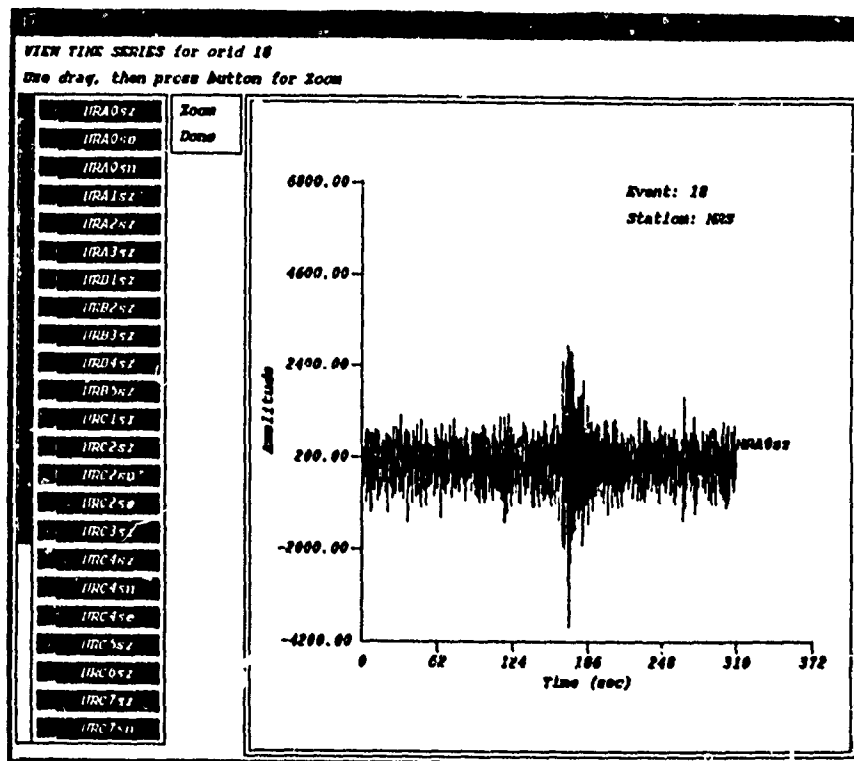
In the left part of the window is a scrollable set of check boxes containing the channel names available for the event. When any of the boxes is selected, the raw waveform for the channel selected is displayed. The user can click down through all the waveforms for the purpose of previewing the data and noting channels which have defective data. These channels can then be deleted from the IBEAM processing by one of the SELECT functions, described below.

The *INCOHERENT BEAMS* option initiates the *VIEW IBEAMS* process which allows the user to display the incoherent beam computations which have been made. This same interface is displayed if the *VIEW IBEAMS* option is selected from the Spreadsheet. This option causes the following subwindow to be displayed:

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Incoherent beams: Current Event
Done

Filter Frequency Band

2.0 - 4.0
2.5 - 4.5
3.0 - 5.0
4.0 - 6.0
5.0 - 7.0
6.0 - 8.0
8.0 - 10.0
9.0 - 16.0

Frequency
Vector Mean
Vector Meansq
Log RMS
Log Mean

Event: 18 NRS
Beam offset: 1.60

16.00

8.0 - 16.0

12.00

8.0 - 10.0

6.0 - 8.0

8.00

5.0 - 7.0

4.0 - 6.0

3.0 - 5.0

4.00

2.5 - 4.5

2.0 - 4.0

0.00

Feature Amplitude

0   100   200   300   400   500

Time (sec)
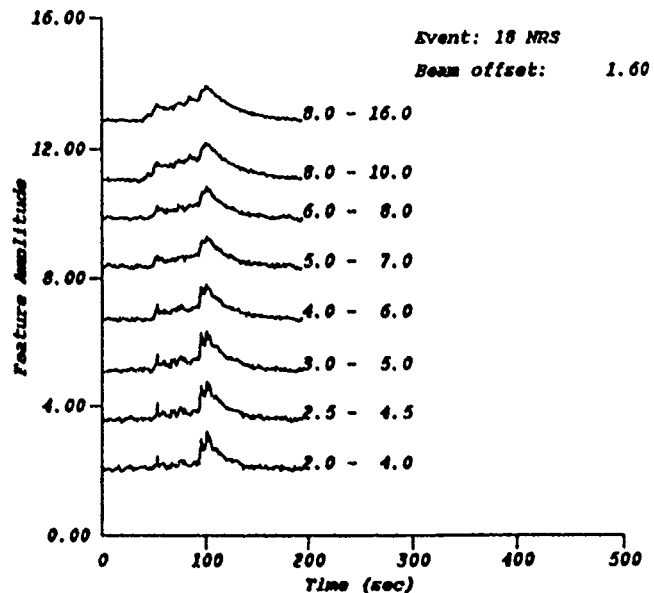
This subwindow contains three smaller windows. The one labeled *Filter Frequency Band* lists the filter bands for which incoherent beams have been computed for the current event. Check boxes appear to the left of each filter which can be moused to select incoherent beams to be displayed. The window to the right contains three windows, five entries, labeled *Frequency*, *Vector Mean*, *Vector Meansq*, *Log RMS*, and *Log Mean*. The check boxes to the left of these options can be moused to select one of the functions. The window above shows *Log RMS* incoherent beams for all filters. If the option *Vector Meansq* is selected, the display is changed to the following.

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Incoherent beams: Current Event
Done

Filter Frequency Band	Frequency
2.0 - 4.0	Vector Mean
2.5 - 4.5	Vector Meansq
3.0 - 5.0	Log RMS
4.0 - 6.0	Log Mean
5.0 - 7.0	
6.0 - 8.0	
8.0 - 10.0	
8.0 - 16.0	

Event: 18 NR3
Beam offset: 1160000.00

(Plot — Feature Amplitude vs Time (sec))

12000000.00 —
8700000.00 —   8.0 - 16.0
                8.0 - 10.0
                6.0 - 8.0
5400000.00 —   5.0 - 7.0
                4.0 - 6.0
2100000.00 —   3.0 - 5.0
                2.5 - 4.5
                2.0 - 4.0
-1200000.00 —

0   100   200   300   400   500
Time (sec)
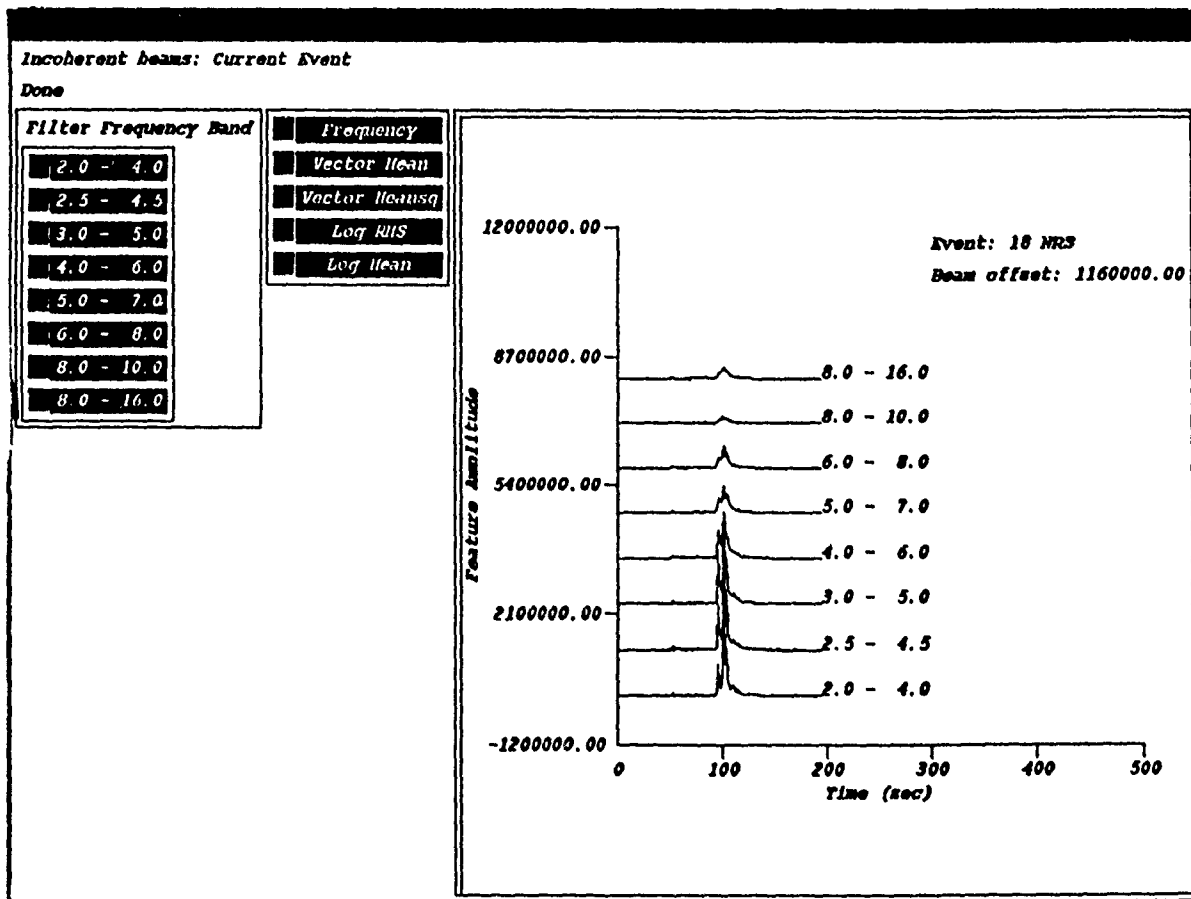
7.2.1.3 SELECT Menu Options

The **SELECT** menu has options for controlling the input parameters to the IBEAM process.

SELECT
- STATION
- FILTERS
- CHANNELS
- TIME RANGE

STATION brings up a window listing all the stations for which waveform data is available for the current event. Each station name has a check box to the left for selecting the station to process. Mousing on the *DONE* button returns to the top level display.

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The example to the left shows the case when there is only one station. In this case, the station is always selected.

FILTER brings up a window, labeled *SELECT FILTERS*, which contains the filters which can be applied to the waveforms prior to computing the incoherent beams. The check boxes to the left of each filter band can be moused to select the prefilter to be applied to the waveforms, whereas mousing on selected filter bands will unselect the filter band. *Default* selects the last filter only, *Select All* selects all the filters, *Clear* removes all selections, and *Done* returns to the top level.

CHANNELS displays a scrollable window containing check boxes for all the channels available for the station. Mousing the check boxes selects the channels to be used in the computations, whereas mousing on selected channels will unselect them. *Default* selects the default channels, which is all vertical components. *Select All* selects all the channels displayed. *Select All sz channels* selects all the vertical component channels. *Clear* removes all selections, and *Done* returns to the top level.

TIME RANGE displays *Enter parameters* subwindow for entering time window parameters for IBEAM, shown below:

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```
Enter Parameters
[Done]
Data Sample rate = 40.000000
NUMBER OF POINTS PER WINDOW:              [40    ]
NUMBER OF POINTS FOR SHIFT:               [40    ]
SIGNAL START POINT:                       [2401  ]
NOISE START POINT:                        [201   ]
NUMBER OF SIGNAL POINTS TO PROCESS:       [8000  ]
NUMBER OF NOISE POINTS TO PROCESS:        [2000  ]
Click Here to use drag for signal and noise selections
```

The numbers shown in the boxes are the default values. The user may change any of them by placing the mouse cursor into the appropriate box, deleting the currently entered number, and typing in the new number. A second option is to use the drag method to select the time parameters, which is activated by mousing on the long button at the bottom of the window, resulting in the display of the following subwindow:
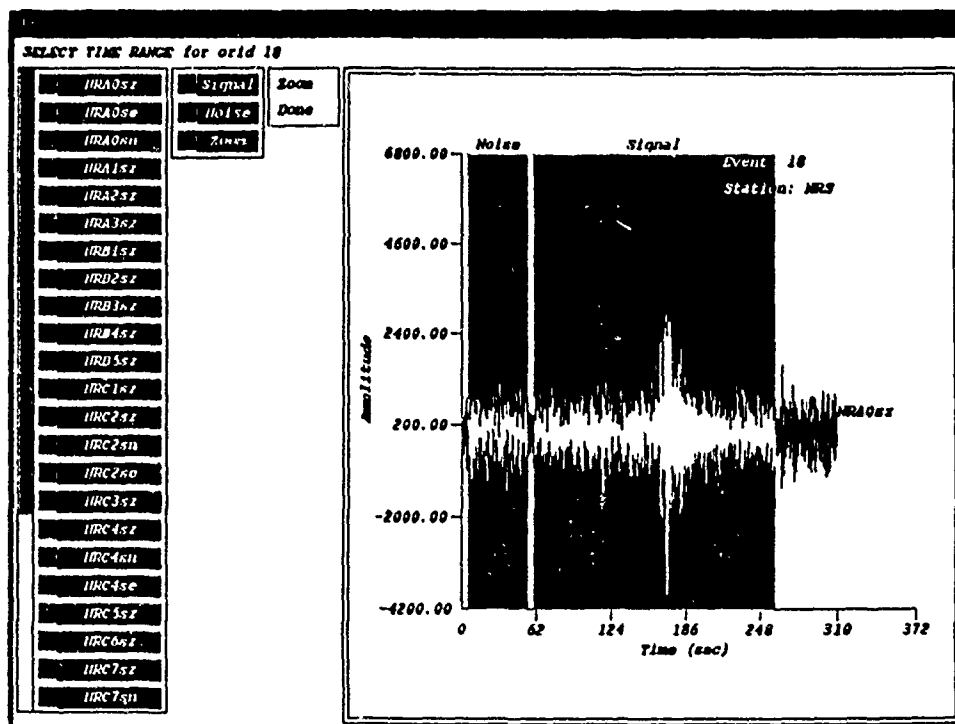
The scrollable check boxes to the left show all the available channels for the event. Any check box can be selected to change the waveform on the right. The signal and noise time interval can be chosen by selecting either *Signal* or *Noise* and then selecting the desired time interval on the waveform by dragging with the left mouse button. The selected time intervals are shown darkened in and appropriately labeled. When *Done* is selected, the window is removed and the *Enter parameters* window is again exposed, with the appropriate time parameter, selected by the drag method, entered into the box. When the *Done* button is moused, the parameters are set and the *Enter parameters* window is removed.

7.2.1.4 EXECUTE Menu Options

```
┌────────────────────────────────────────────────────────────┐
│  ┌──────────────────────────────────────────────────────┐  │
│  │            INCOHERENT BEAM PROCESSING                 │  │
│  ├──────────────────────────────────────────────────────┤  │
│  │ ┌────┐ ┌────┐ ┌──────┐ ┌────────┐                     │  │
│  │ │FILE│ │VIEW│ │SELECT│ │EXECUTE │                     │  │
│  │ └────┘ └────┘ └──────┘ └────────┘                     │  │
│  │                    ┌──────────────────┐               │  │
│  │                    │    SELECTION     │               │  │
│  └────────────────────┴──────────────────┴───────────────┘  │
└────────────────────────────────────────────────────────────┘
```
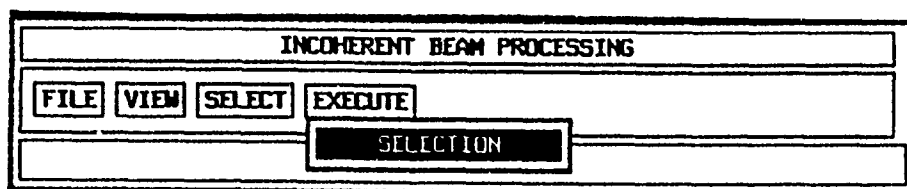
The single option under **EXECUTE** is *SELECTION*, which initiates the IBEAM process using the default or user selections. The IBEAM process can take a long time to complete, depending on how many channels are used and how many time windows are selected. Thus, selecting *SELECTION* causes a subprocess, called STACOMP, to begin, which runs independently of IBEAM. The *SELECTION* option remains displayed until the process has begun. When this process begins, it will run in the background and the *SELECTION* option will be removed. At this point, the user can continue to make menu selections, execute additional processes, or quit the IBEAM interface while the STACOMP process is still running. When the STACOMP process has been completed, a process display icon, discussed in Section 3.5, will be displayed which will be mouse-sensitive. This icon will be displayed in the upper right of the monitor, regardless of whether or not the original IBEAM process is still running. If the icon is moused, the *VIEW IBEAMS* process will be initiated which allows the resultant beams to be displayed, as described in Section 7.2.1.2.

7.2.2 Fourier Spectral Analysis (FSDISPLAY)

FSDISPLAY provides the user interface for setting up the inputs for the process to compute and store single and/or array-averaged power spectra for specific seismic phases and

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viewing the results. This process can also be invoked from the automated process with little or no user interaction.

Fourier spectra of seismic phases are used in a number of discriminants. The most important examples are *Ripple-Fire*, which looks for spectral modulations or spectral scalloping as an indication of multiple explosions, and spectral ratio on regional phases, most notably, the *Lg* phase. FSDISPLAY computes spectra for specific phases and provides a number of options for smoothing and correcting the spectra. When array data are available, the most stable spectra can be obtained by averaging across the array the spectra computed for individual channels of the array. In a sense, array-averaged spectra are the frequency-domain equivalent to incoherent beams computed in the time domain. Options are also available to the user to change the window length and shape and how many data points are used to compute spectra.

FSDISPLAY also has the capability of correcting the spectra for noise, instrument, and von Seggern-Blandford source scaling. These scaling options are available interactively for research purposes. However, most of the discriminants which use spectra assume that no corrections have been made.

FSDISPLAY can be initiated from the **PROCESS** menu of the Spreadsheet by selecting the *SINGLE SPECTRUM* option and also from summary displays for discriminants which use spectra.

When the FSDISPAY process is initiated for a selected current event, a subwindow is created which contains the FSDISPLAY menubar, which has the standard menus discussed above in Section 7.1.

7.2.2.1 FILE Menu Options

The **FILE** menu currently has only one option, *QUIT*, which exits the FSDISPLAY process and returns control to the spreadsheet. The *OPEN* option, for opening the database to bring in another event, has not been implemented.

7.2.2.2 VIEW Menu Options

The **VIEW** menu allows the user to preview the raw waveforms, view computed incoherent beams for the event, and to display previously computed spectra.
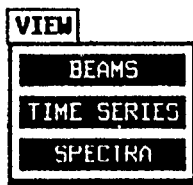
If the *VIEW BEAMS* option is selected, the subwindow shown below is displayed.
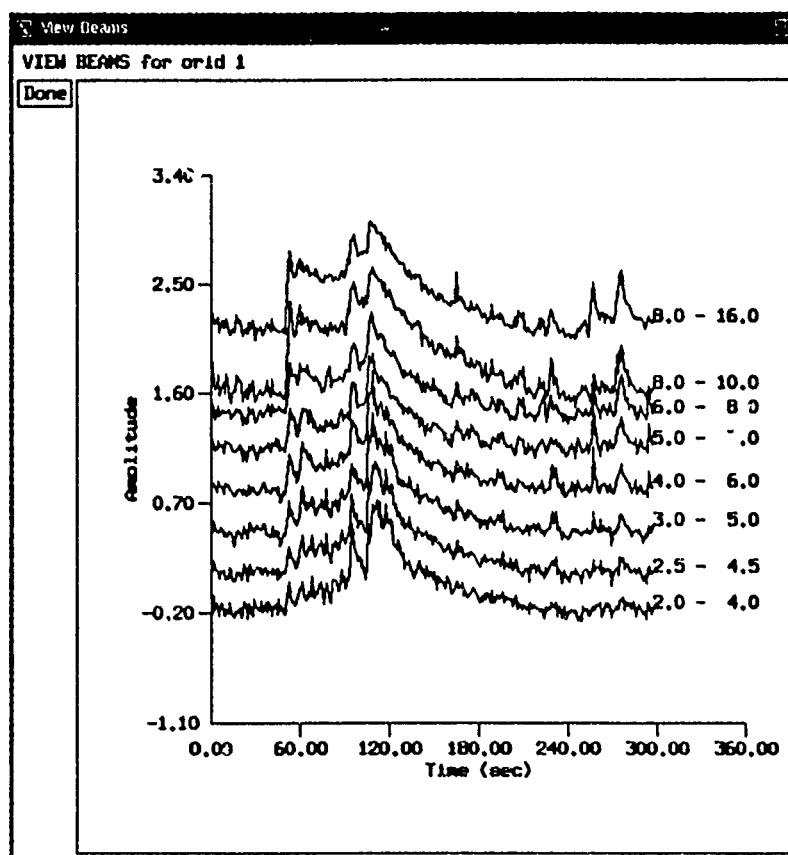
This window shows the selected incoherent beams which have been computed for the event. The windows for computation of spectra are set on incoherent beams, as discussed below in Section 7.2.3. Mousing on the *DONE* button removes the display.

TIME-SERIES displays the subwindow shown below:
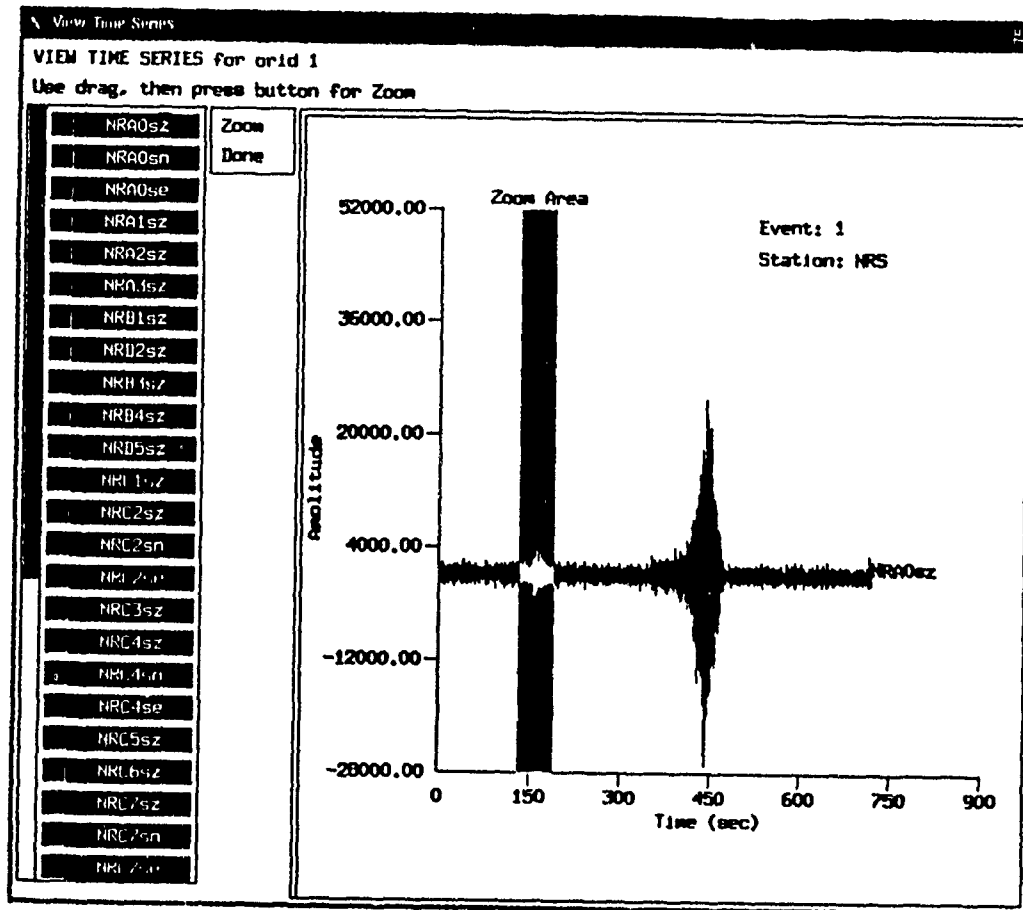
This display is the same interface as the *VIEW WAVEFORMS* option for the IBEAM interface, explained in Section 7.2.1.2. The display above shows how to use the *Zoom* option. The *Zoom Area* is selected by dragging with the left mouse over the area to be zoomed. When the *Zoom* button is moused, the waveform is displayed with expanded time scale corresponding to the *Zoom Area*, as shown below:
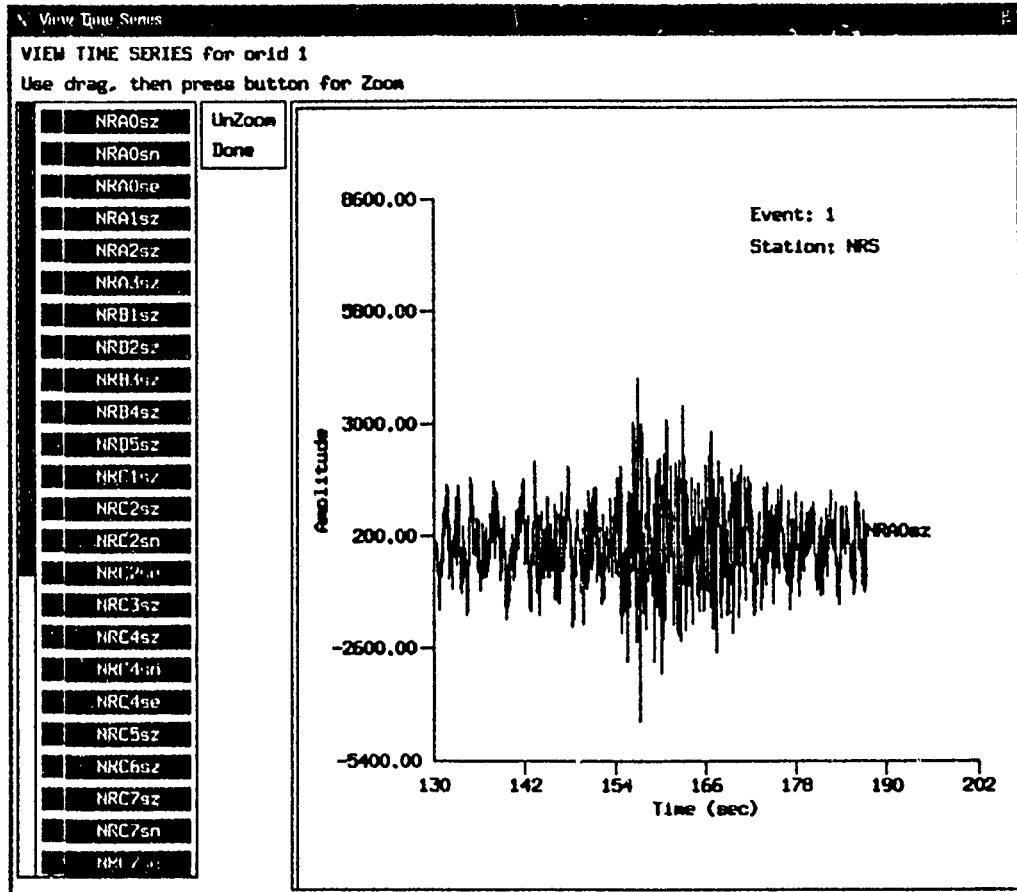
Selecting the *SPECTRA* option displays the following subwindow:
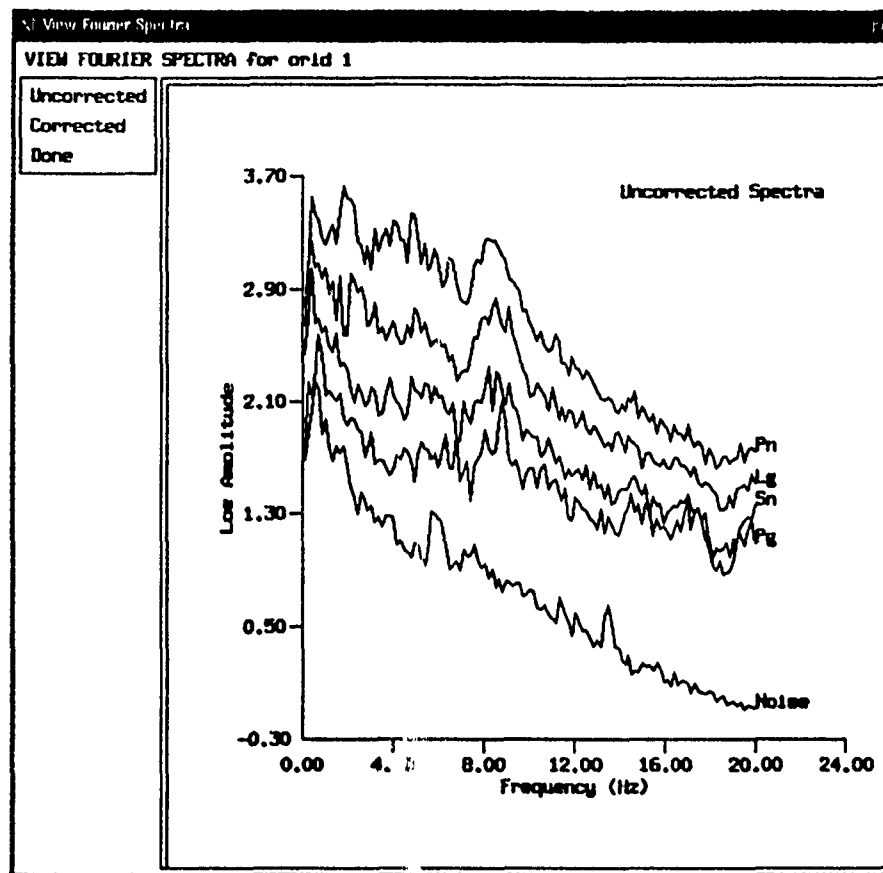
This window shows the uncorrected spectra initially, assuming the spectra have been computed. If the *Corrected* button in the upper-left corner of the window is pressed with the mouse, the corrected spectra are displayed, as shown below for instrument and Q corrected spectra:

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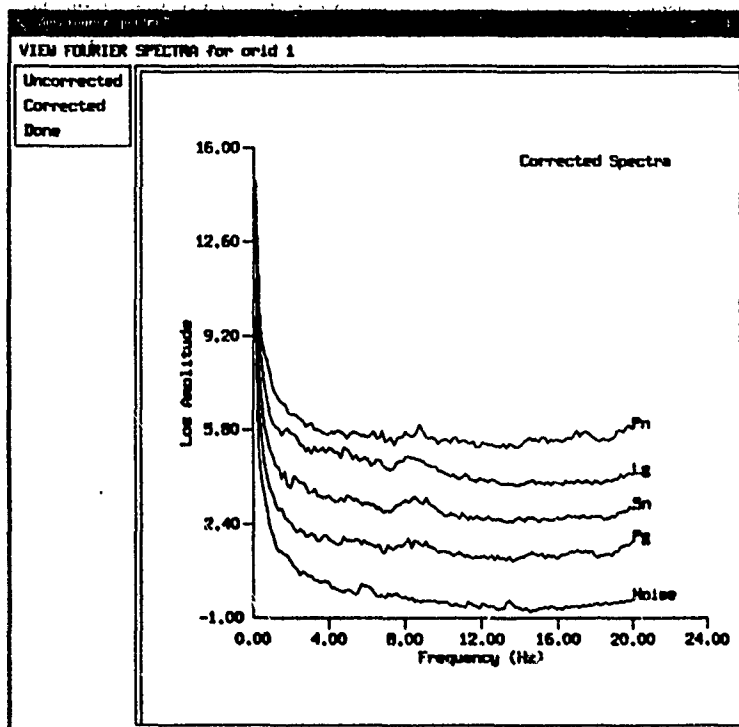
These spectra are only displayed if they have been previously computed.

7.2.2.3 SELECT Menu Options

The **SELECT** menu has options for controlling the input parameters to the FSDISPLAY process.

STATION brings up a window listing all the stations for which waveform data is available for the event. This display is the same as that described in Section 7.2.1.3.

CHANNELS displays a scrollable window containing check boxes for all the channels available for the station. This display is the same as that described in Section 7.2.1.3.

TIME RANGE allows the user to select windows for spectral computations. Selecting this option displays the subwindow shown below:
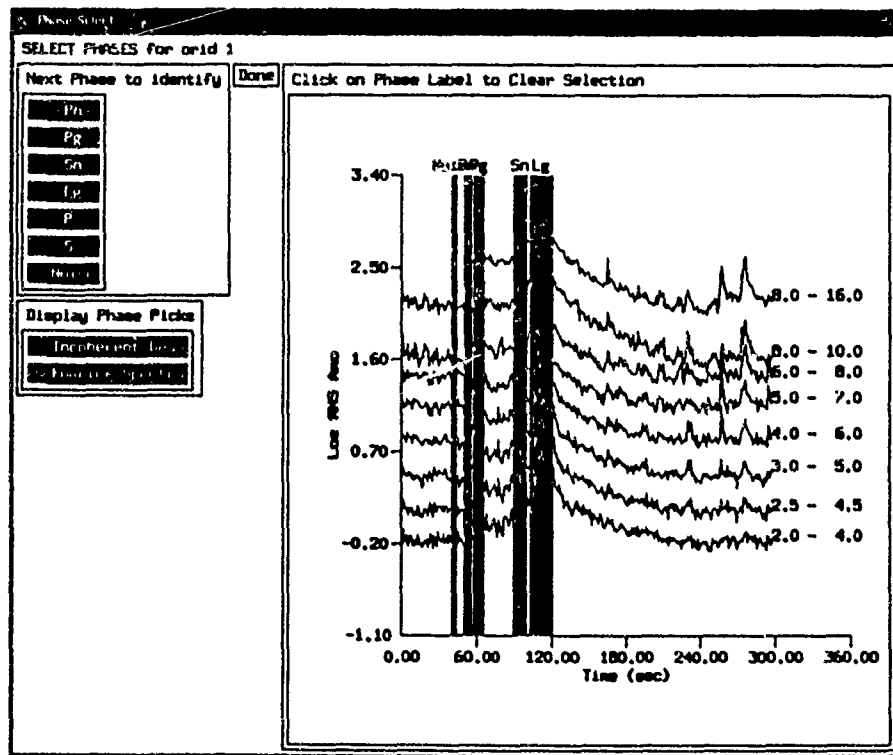
The main window shows plots of the incoherent beams previously computed for the event. If phases have been previously selected, in processes such as ARDISPLAY (Section 7.3.1) or DTW (Section 7.4.4), these selections will be darkened in, as shown. If phases have not been selected, they may be selected, using the *PHASE SELECT* method, which is explained in Section 7.3.1. In addition to selecting phases, a noise segment must also be selected.

If the *SMOOTHING* option is selected, the subwindow shown below is displayed:

```
┌─────────────────────────────────────────────────────┐
│ [N] Select Smoothing Parameters                  [E] │
├─────────────────────────────────────────────────────┤
│ SELECT SMOOTHING PARAMETERS for orid 1              │
│ ┌─────┐                                             │
│ │Done │                                             │
│ └─────┘                                             │
│ Noise Window Length (pts) = 160                     │
│ Signal Window Length (pts) = 160                    │
│ PERCENT TAPER ON TIME SERIES:      │5.00         │   │
│ NUMBER OF POINTS IN FFT:           │256          │   │
│ NUMBER OF TIMES TO SMOOTH STACKED FFT: │1        │   │
└─────────────────────────────────────────────────────┘
```

Spectral smoothing is accomplished by applying a cosine taper in the time domain or by convolving the spectrum with a three-point Hanning window in the frequency domain. The Hanning window smooth also results in decimation of the spectrum. The percent of the time-series to apply the cosine taper, the number of fft points to use, and the number of times to apply the Hanning smooth can be entered in this window. The default number of points in the fft is set to be the next power of two greater than the longest window selected.

The *CORRECTION* option allows various corrections to be made to the spectra. The user-selectable corrections include noise subtraction and deconvolution of the instrument response and the von Seggern-Blandford explosion source model. These options are selected from the check boxes in the subwindow displayed by *CORRECTION*, shown below:

```
┌─────────────────────────────────────────────────────────────┐
│ [N] Spectral Correction Parameters                       [T] │
├─────────────────────────────────────────────────────────────┤
│ SELECT CORRECTION PARAMETERS for orid 1                     │
│ ┌─────┐                                                     │
│ │Done │                                                     │
│ └─────┘                                                     │
│                                        YES   NO             │
│ ┌─────────────────────────────────────┬───┬───┐            │
│ │ Remove Noise from Signal            │ □ │ ■ │            │
│ │ Remove Instrument Response          │ ■ │ □ │            │
│ │ Remove VonSeggern-Blanford Response │ ■ │ □ │            │
│ └─────────────────────────────────────┴───┴───┘            │
│                                                             │
│ YIELD:                      │5.08      │  ┌──────────────┐  │
│ COUPLING TERM:              │16.80     │  │ ■ Granite    │  │
│ MEDIUM DEPENDENT CONSTANT (a):  │0.00  │  │ □  Tuff      │  │
│ MEDIUM DEPENDENT CONSTANT (k0): │0.00  │  └──────────────┘  │
└─────────────────────────────────────────────────────────────┘
```

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Note: For a given event, only two sets of spectra are produced, corrected and uncorrected. It is not possible to have more than one kind of corrected spectrum. Also, for discrimination purposes, it is important that uncorrected spectra are computed. Many of the discriminants assume the spectra are uncorrected and make their own corrections, if necessary. Spectral corrections have been included in FSDISPLAY only for research purposes.

SNR is an option for measuring the signal-to-noise ratio on any phase in a user-selected frequency band. Selection of this option displays the window shown below:
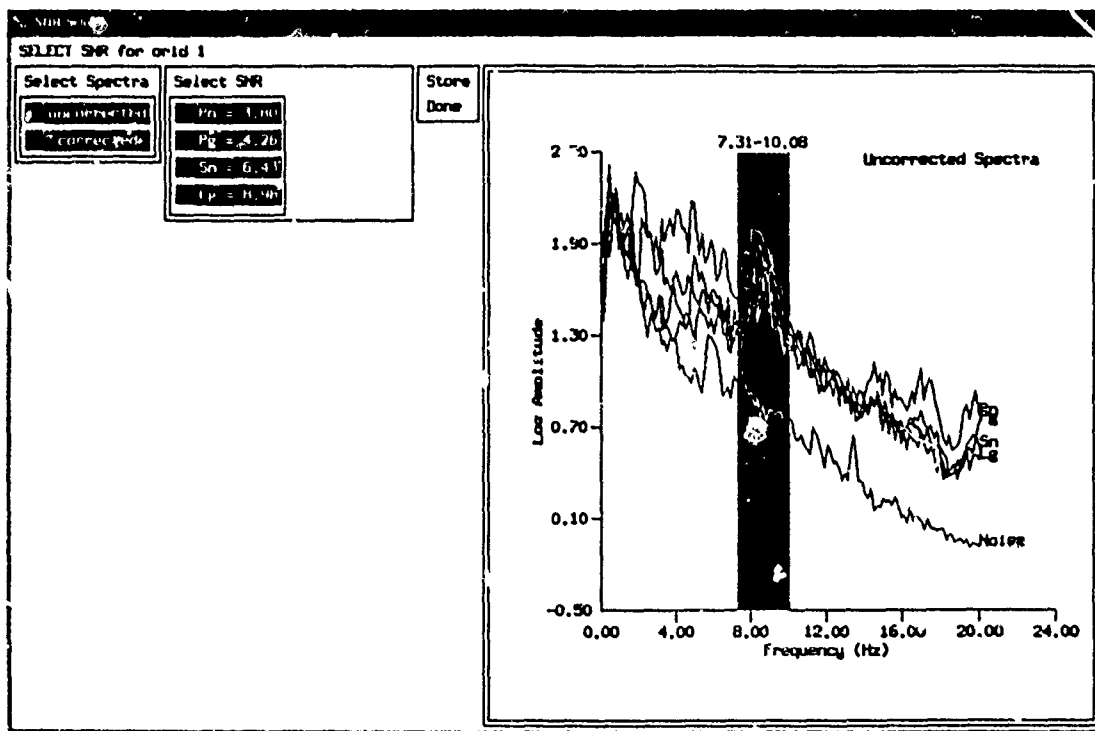
This window contains three subwindows for measuring the signal-to-noise ratios. The window to the right shows the spectra for all the phases associated with the event. The frequency band for the measurement is selected by dragging with the left mouse button on the spectra. The

selected frequency band is then darkened-in and labeled. *Select Spectra* selects whether to use corrected or uncorrected spectra in the measurement. When the frequency range has been selected, a mouse click on *Store* will compute and store the measured signal-to-noise ratios. The values are then displayed in the *Select SNR* subwindow.

7.2.2.4 EXECUTE Menu Options

```
┌─────────────────────────────────────────────────────────┐
│ ┌───────────────────────────────────────────────────────┐ │
│ │            FOURIER SPECTRA for Grid 1                  │ │
│ └───────────────────────────────────────────────────────┘ │
│ ┌──────┐ ┌──────┐ ┌────────┐ ┌─────────┐                 │
│ │ FILE │ │ VIEW │ │ SELECT │ │ EXECUTE │                 │
│ └──────┘ └──────┘ └────────┘ └─────────┘                 │
│                            ┌─────────┐                    │
│ ┌──────────────────────────│ SPECTRA │──────────────────┐ │
│ │                          └─────────┘                  │ │
│ └───────────────────────────────────────────────────────┘ │
└─────────────────────────────────────────────────────────┘
```
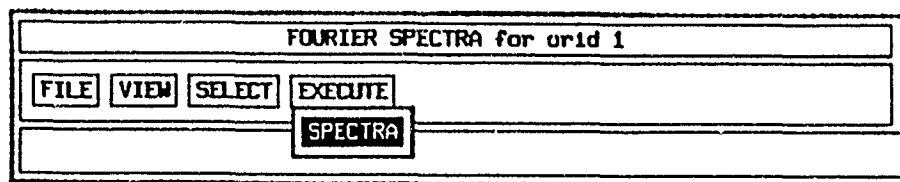
The single option under **EXECUTE** is *SPECTRA*, which initiates the FSDISPLAY process using the default or user selections. The *SPECTRA* option remains displayed until the process has completed.

7.3 DISCRIMINANT PROCESSING AND DISPLAY FUNCTIONS

ISEIS currently has four graphics interfaces which allow the user to compute discriminant features and display them. Three of the discriminant features, amplitude ratio (ARDISPLAY), spectral ratio (SRDISPLAY), and dynamic time warp (DTW), display the features of the current event against those for reference events. These interfaces allow the user to do interactive case-based event characterization. The fourth, multiple event recognition system (MERSY), which identifies ripple-fired events, displays spectra and cepstra of the current event and allows the user to interactively identify cepstral peaks.

7.3.1 Amplitude Ratio (ARDISPLAY)

The ARDISPLAY program allows the user to compute and examine amplitude ratios of regional phases and to compare them with those of reference events. This interface is designed to be a research tool to investigate amplitude ratios measured on a variety of regional phases in several different frequency bands. The interface is useful for examining these features for different geographic regions and to aid in defining parameters for event identification rules in the routine processing. The user can examine many more ratios than the three now implemented as regional phase ratio discriminants, namely, *Max PS*, *HF Pn/Sn* , and *HF Pn/Lg*.

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All amplitude ratio measurements in ISEIS come from the filtered incoherent beams. ARDISPLAY cannot be run until incoherent beams have been computed for the event. Ratios are also computed for phases which are defined and selected by a special drag method, which is provided by the phase-selection option. Thus, the phases selected in ARDISPLAY from the incoherent beam have a beginning time and end time. This "time duration" feature of phases selected this way allows amplitude measurements on phases to be defined as averages over the time-duration window, in addition to the peak amplitude in the window. Also, in its current implementation, ARDISPLAY always uses the root-mean square incoherent beams for amplitude measurements.

The ARDISPLAY function can be initiated either from the **PROCESS** menu option of the Spreadsheet or from any of the summary display windows for the amplitude ratio discriminants. When this process is initiated for a selected current event, a subwindow is created containing the ARDISPLAY menubar, which has the standard menus discussed in Section 7.1.

### 7.3.1.1 FILE Menu Options


The **FILE** menu currently has only one option, *QUIT*, which exits the IBEAM process and returns control to the Spreadsheet. The *OPEN* option, for opening the database to bring in another event, has not been implemented.

7.3.1.2 VIEW Menu Options

The **VIEW** menu allows the user to view the results of amplitude ratios and to compare the measurements of the current event against those obtained for reference events.
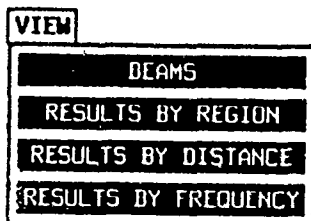
BEAMS displays all the incoherent beams computed for this event. This display is the same as the *VIEW BEAMS* option of FSDISPLAY, discussed in Section 7.2.2.2.

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RESULTS BY REGION allows the user to compare amplitude ratios measured for the current event with those for reference events in defined reference regions. When this option is selected, the following subwindow is displayed:

The scrollable part of the window contains the names of all the reference regions and the distances of the region centroids from the current event *(DE)* and from the station *(DS)*, in km. To the left of each name is a check box which can be moused by the user to select the reference region to be displayed. *Default* selects the last entry, *Select All* selects all the entries, and *Clear* removes all selections. After all the region selections have been made, pressing the *Done* button brings up the window shown below:

This window has several check boxes for selecting what data to display. The frequency band for displaying the data is selected from the *SELECT FILTERS* check boxes. The ratios to plot are selected from the *SELECT RATIOS* check boxes. The two options under *SELECT METHODS* relate to the two methods for computing the regional phase amplitudes. The two

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methods are *icbave*, wh   he phase amplitude is the average rms amplitude in the selected time interval for the phase, and , *bmax*, where it is the maximum amplitude in the time window. Under *SELECT PLOT TYPE*, *All Ratios* plots all the data points, whereas *Mean Ratios* only plots the amplitudes averaged over all the events in the region and error bars representing the standard deviation of the values. After the desired plot parameters have been selected, the plots of amplitude-by-region will be displayed when *Plot* is moused. When the *Done* button is moused, the windows are removed and control returns to the top level. An example of high frequency (8 to 16 Hz) *Pn /Lg* amplitude ratios, where *All Ratios* was selected, is shown below:
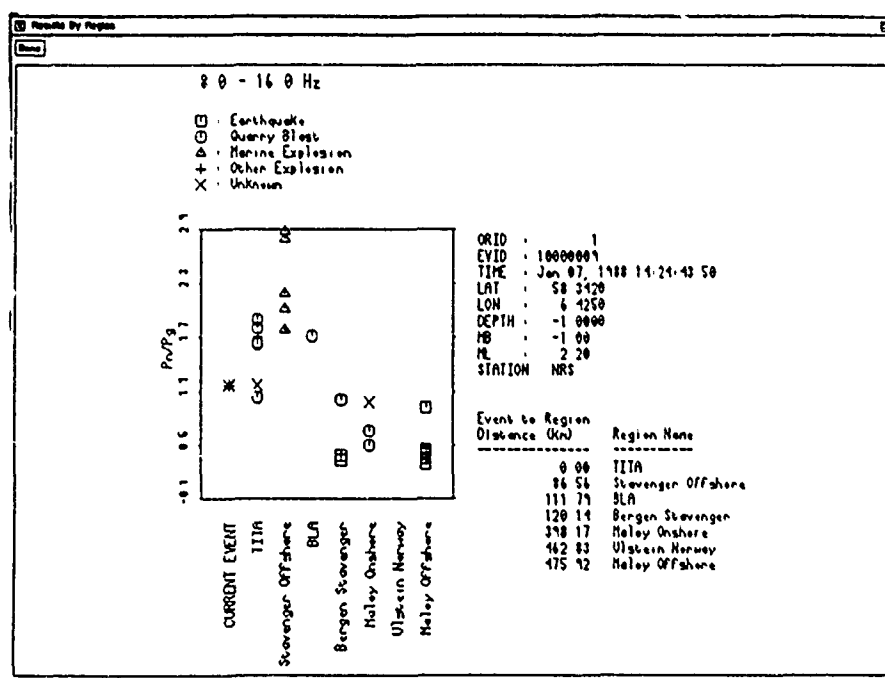
The CURRENT EVENT is plotted along with all the data for all the selected regions, in order of distance from the current event. On a color monitor, this display is color-coded for event type the same as on the Spreadsheet and Map. A legend is displayed at the top of the window showing the symbols and colors used for different event types. If the *Mean Ratios* option is selected, the following plot is displayed:

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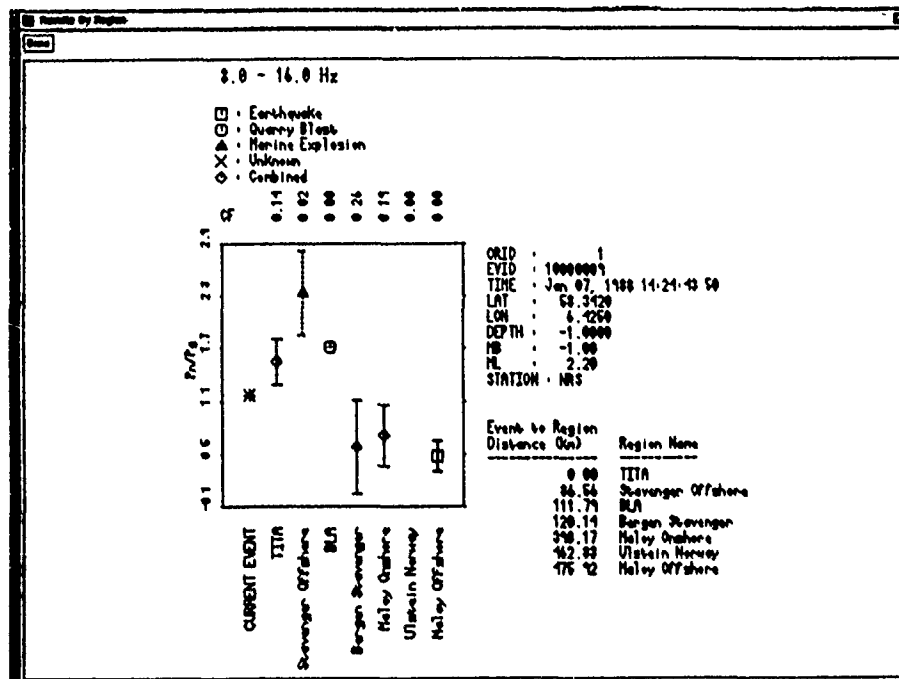
In this plot, the error bars are centered on the mean values and show the standard deviations in the measurement over the region. At the top of the plot, CF refers to "confidence factor." The numbers to the right of CF are confidence factors computed by assuming that the feature values in each region are normally distributed with standard deviations represented by the error bars. The CF values are the probabilities that the current-event feature value comes from the distribution of values for each region. In both of these plots, the plots are removed when the DONE button is pressed.

RESULTS BY DISTANCE displays the data as a function of the event-to-station distance. Regions are selected in the same way as in **RESULTS BY REGION**, using a region-selection subwindow. Another subwindow is displayed for selecting the data to be plotted, which is similar to that described above for **RESULTS BY REGION**. The events plotted by distance are those in the selected regions. The current event is plotted as an asterisk symbol, as shown below for the *Pn/Lg* amplitude ratio:
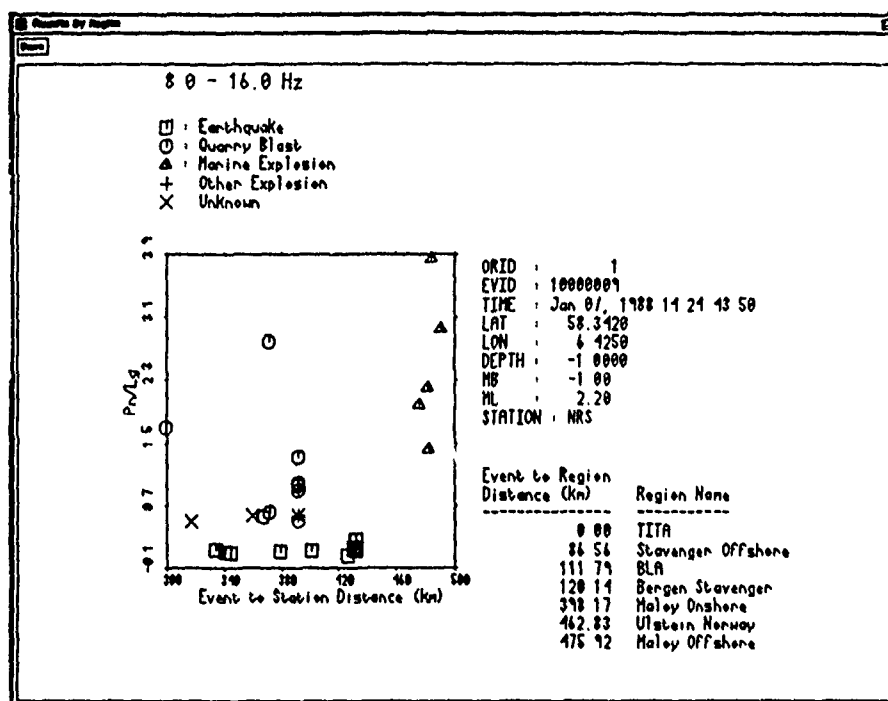
For color monitor displays, the same event-type color coding as on the Map and the Spreadsheet are used. Selecting *DONE* removes the plot. *RESULTS BY FREQUENCY* displays amplitude ratios for the current event and reference events as a function of filter frequency. Reference regions are selected in the same way as in *RESULTS BY REGION* and the reference events in these regions are displayed. Another subwindow is displayed for selecting the data to be plotted, which is similar to that described above for *RESULTS BY REGION*. An example of the *Pn/Lg* ratio plotted as a function of frequency is shown below:
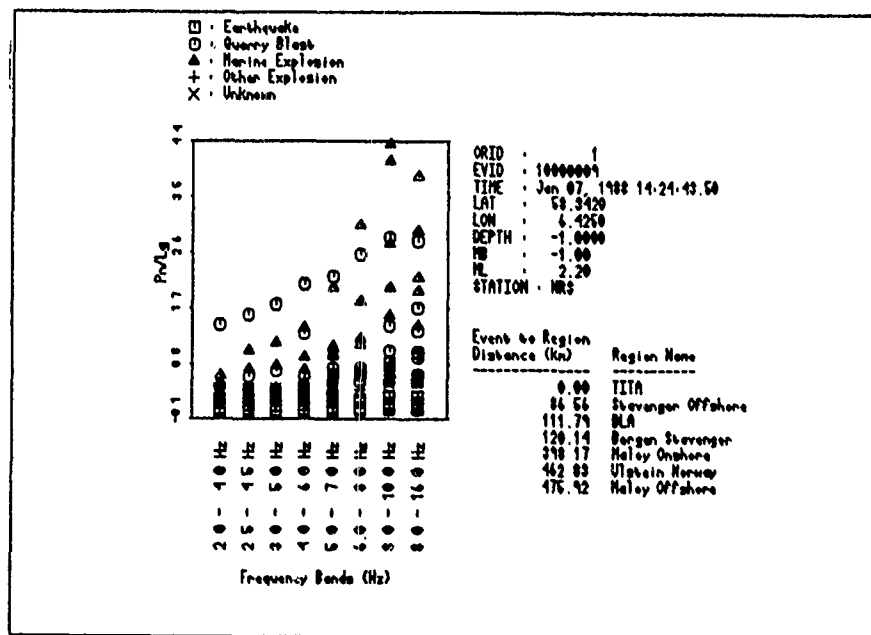
The current event is plotted as an asterisk symbol amidst the data points for the selected reference events. On a color monitor, the asterisk is white and the other symbols are color-coded for the event type in the same way as on the Spreadsheet and Map.

7.3.1.3 SELECT Menu Options

The *SELECT* menu options allow the user to set up parameters for computing amplitude ratios which are displayed in the *VIEW* functions, described above.
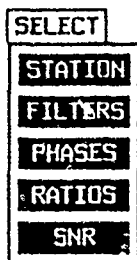
STATION brings up a check box window for selecting the stations for which incoherent beam data is available for computing amplitude ratios. This display is the same as that described in Section 7.2.1.3.

FILTERS displays a window containing check boxes for all the filter frequency bands for which incoherent beams have been computed. The incoherent beams for the selected filter bands will be displayed to the user in the *PHASES* option, described below, and will be used for computing the ratios. This interface is identical to the one described for IBEAM in Section 7.2.1.3.

PHASES displays a subwindow, shown below, which allows the user to select phase regions or stapick features, described in Section 2.2.2, on incoherent beams:
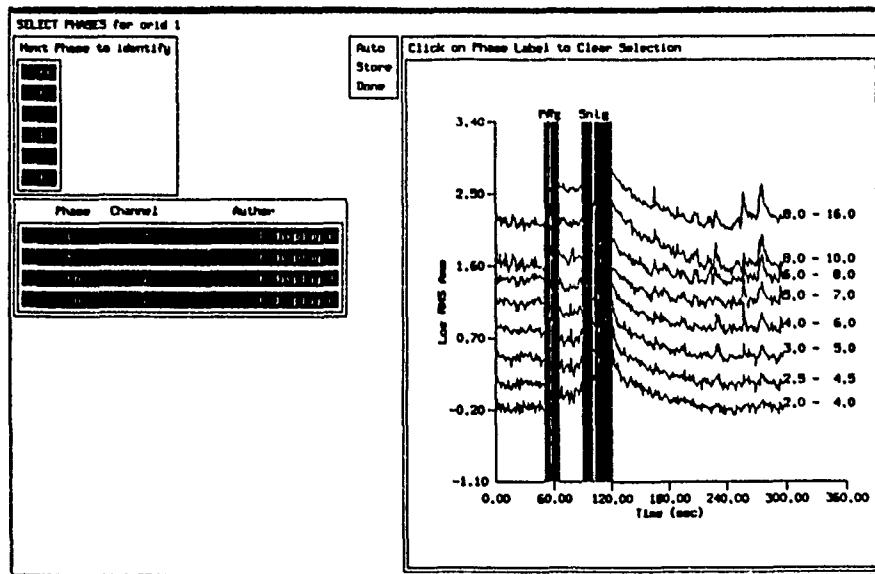
Phase stapicks can be selected either manually or automatically. In the manual mode, the user selects the phase to be defined in the subwindow labeled, *Next phase to identify,* by mousing on the check box for the appropriate phase to define. Then, the phase region is defined by dragging the cursor on the incoherent beam. When this is done, the defined time interval is backgrounded in black and labeled with the designated phase name. To identify more phases, the user must change the selection in the phase selection check box. A phase pick can be deleted by mousing on the phase label at the top of the blackened time interval and a new interval defined. After the phases have been selected, the user must mouse on *Store* in order for the phase picks to be permanently recorded in the database as stapicks.

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In the automatic mode, ISEIS uses previously picked phase times, made in the ARS, to reference the beginning of the phase. These phase picks are displayed in the subwindow below the phase pick subwindow, along with the channel on which the phase was identified, and the name of the user who made the pick. Mousing the check boxes to the left of the phase name causes the associated phase to be indicated with a red cursor on the incoherent beam plots. When the *Auto* button is pressed with the mouse cursor, the time intervals for the phases are then designated assuming the phases propagate at certain group velocities, starting at the previously picked phase times. These time intervals are also blackened-in, as in the case of the interactive picking option. After the user is satisfied with the phase stapick selection, the user must press *Store* to compute the stapick features, i.e., the maximum *(MAX)* and average *(AVG)* amplitudes in the stapick window, and to permanently retain the features in the database.

Note: ISEIS only allows the user to select phase start time and intervals on incoherent beams from the phase select options. To make phase picks on waveforms, the ARS must be used.

```
 Ratio Select                                          

SELECT RATIOS for orid 1

┌──────────┬─────────────┐ ┌─────────┐ ┌─────────────┐
│ Numerator│ Denominator │ │ ■ MAX   │ │ Default     │
│    Pn    │     Pg      │ │ ■ AVG   │ │ Select All  │
│    Pn    │     Sn      │ └─────────┘ │ Clear       │
│    Pn    │     Lg      │             │ Done        │
│    Pg    │     Sn      │             └─────────────┘
│    Pg    │     Lg      │
│    Sn    │     Lg      │
│   Pmax   │    Smax     │
│          │             │
│          │             │
└──────────┴─────────────┘
```

RATIOS brings up a subwindow that allows the user to pick the ratios to be determined. The *Numerator* and *Denominator* can be picked by mousing on the appropriate entries. Either *MAX* or *AVG* or both can be selected in the check boxes to select maximum or average amplitude

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measurements. Finally, options can be selected to automatically select all ratio possibilities, using *Select All*, or to clear all selected options to start over, using *Clear*. When all desired ratio options have been selected, mousing on the *Done* button will store the selections and remove the subwindow.

SNR provides an interface for computing and storing signal-to-noise measurements on phases using incoherent beam measurements. This option produces a subwindow which displays all selected incoherent beams and allows phases to be selected for the measurement of signal-to-noise ratio, as shown below.
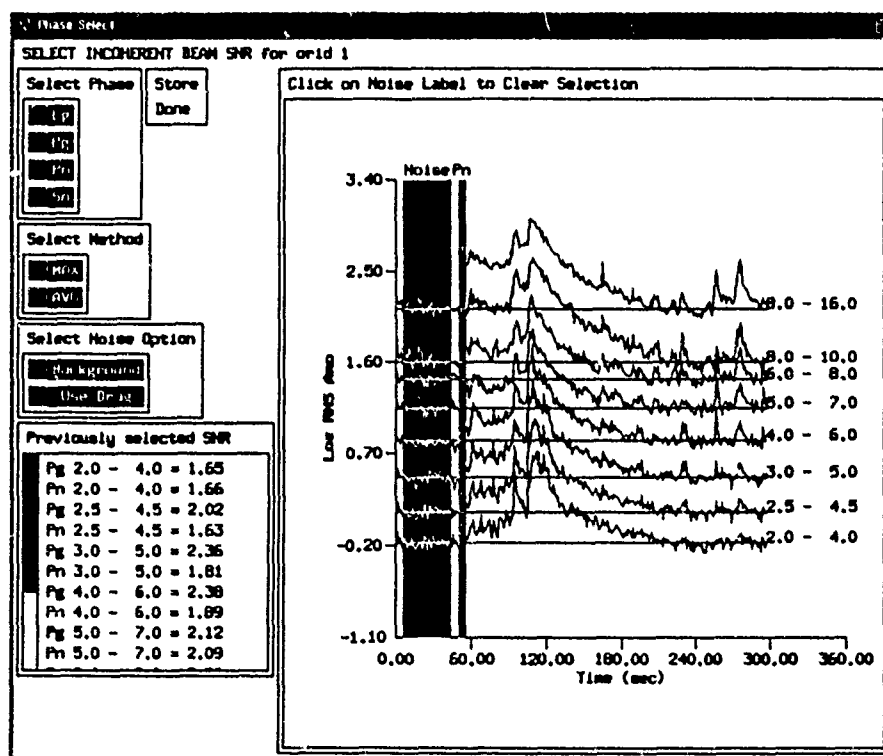
The window labeled *Select Phase* is used to select the phase to measure the signal-to-noise ratio. *Select Method* allows the user to select either the average *(AVE)* or maximum *(MAX)* amplitude to be computed. *Select Noise Option* allows the user to either use the background noise that was computed in the IBEAM process, whose average is plotted as

horizontal straight lines on the incoherent beam plots, or the noise average can be selected from the plot by mouse drag. The selected regions for signal and noise are so labeled on the incoherent beam plots. The window labeled *Previously selected SNR* shows previously computed values of signal-to-noise ratios.

7.3.1.4 EXECUTE Menu Options

```
┌─────────────────────────────────────────────────────────────┐
│ ┌─────────────────────────────────────────────────────────┐ │
│ │              AMPLITUDE RATIOS for orid 1                 │ │
│ ├─────────────────────────────────────────────────────────┤ │
│ │ [FILE] [VIEW] [SELECT] [EXECUTE]                         │ │
│ │                      ┌──────┐                            │ │
│ │                      │ BEAM │                            │ │
│ │                      └──────┘                            │ │
│ └─────────────────────────────────────────────────────────┘ │
└─────────────────────────────────────────────────────────────┘
```
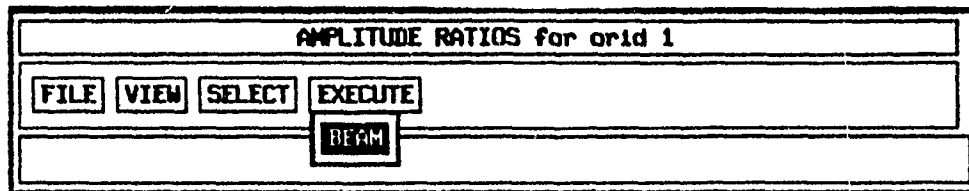
The single option under **EXECUTE**, *BEAM*, initiates the process that computes the amplitude ratios selected. The *BEAM* option remains displayed until the process has completed.

7.3.2 Spectral Ratio (SRDISPLAY)

The SRDISPLAY program allows the user to compute and examine spectral ratios measured on regional phases and to compare them with those of reference events. This interface is designed as a research tool for studying the discriminatory capability of any kind of spectral ratio measured on any regional phase. This interface is useful for examining these features for different geographic regions and to aid in defining parameters for event identification rules in the routine process. Only one spectral ratio discriminant has been implemented in ISEIS, namely, *Lg Spectral Ratio*. However, SRDISPLAY enables the user to examine many other kinds of spectral-ratio measurements on other phases and to study the effects of propagation path attenuation on spectral ratio discrimination. Moreover, other spectral ratio discriminants can be generated by using the *COPY* option under **EDIT** menu of the Spreadsheet to make a duplicate of the *Lg Spectral Ratio* rules. These can then be edited to redefine the parameters or decision criteria to apply to another regional phase, based on the analysis of plots in SRDISPLAY. (See Section 5.4.2 for the description of the rule copying and editing facilities of ISEIS.)

All spectral ratio measurements are made from spectra computed in the FSDISPLAY process, described in Section 7.2.2. Spectra with no corrections should be computed in

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FSDISPLAY. SRDISPLAY can be used to make corrections for noise, instrument, and Q specifically for spectral ratio computation.

The SRDISPLAY function can be initiated either from the **PROCESS** menu option of the Spreadsheet or from any of the summary display windows for the spectral ratio discriminant. When this process is initiated for a selected current event, a subwindow is created containing the SRDISPLAY menubar, which has the standard menus discussed in Section 7.1.

7.3.2.1 FILE Menu Options

This menu is exactly the same as that for the ARDISPLAY function (see Section 7.3.1.1). Currently, the only option which has been implemented is *QUIT*, which exits the SRDISPLAY process and returns control to the Spreadsheet.

7.3.2.2 VIEW Menu Options

The **VIEW** menu has options for the user to view spectra, with various corrections, and to compare the measurements for the current event against those obtained for reference events.
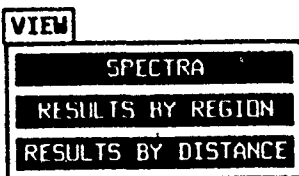
SPECTRA brings up a subwindow which displays all the spectra computed for the event. This display is identical to the one for viewing spectra under the FSDISPLAY interface, described in Section 7.2.2.2.

RESULTS BY REGION displays spectral ratios for the current event in comparison with those of reference events for defined reference regions. The reference regions containing reference events to be displayed are selected in exactly the same way as they are in the *RESULTS BY REGION* option of ARDISPLAY, described in Section 7.3.1.2. After the reference regions are selected, the following subwindow, containing check boxes for all the plot options, is displayed:

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The window labeled **SELECT PHASES** selects the phase for which spectral ratios are to be displayed. **SELECT METHOD** selects spectral ratios which have been computed with one of two different spectral amplitude measurements: maximum *(MAX)* amplitude or the average *(AVE)* amplitude in the spectral bin. **SELECT AMPLITUDE** determines whether logged or unlogged spectral ratios are to be displayed. **SELECT CORRECTIONS** selects what correction method was used on the spectra for which spectral ratios have been computed. **SELECT PLOT TYPE** allows the user to select whether all values are to be plotted, or if the mean values, with error bars for standard deviations, for all events in a region are to be plotted. Finally, **SELECT RATIOS** allows the user to select the specific spectral ratio, in terms of what spectral bins were used in the numerator and denominator, to be displayed. When the **Plot** button is pressed, the selected plots will be displayed in subwindows. Mousing on the **Done** button removes the display and returns control to the top level. An example of a plot of *Lg* rms spectral ratios, where the ratios are between rms spectral amplitudes in the 2-to-6 Hz band to those in the 6-to-10 Hz band with only instrument correction applied, for a current event in western Norway and nearby reference events, is shown below:
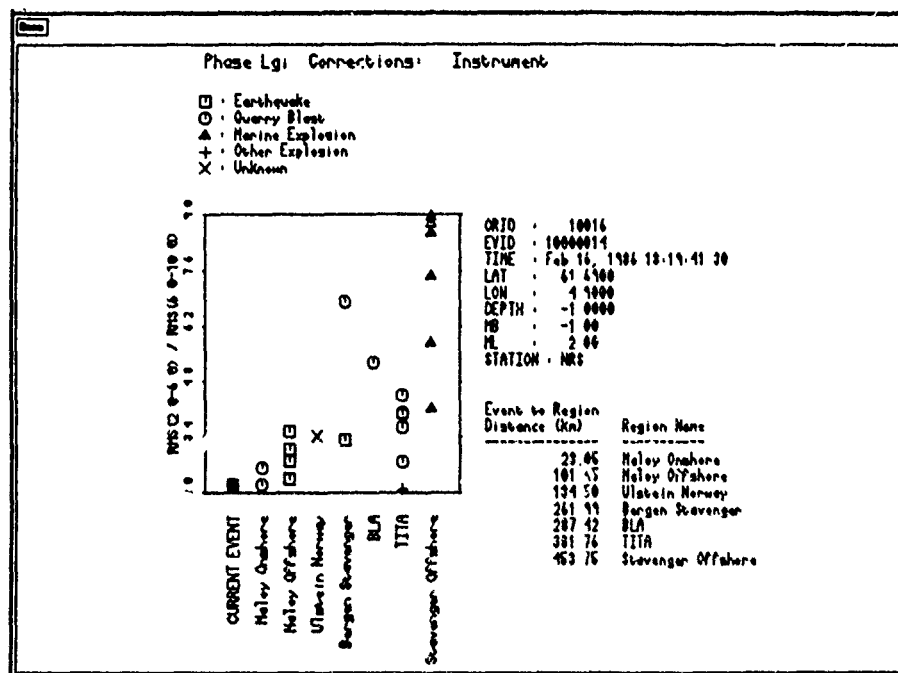
The data are plotted with symbols representing the event types, indicated by the legend above the plot. On a color monitor, the data points are plotted in color using the same color code as that used in the Map and the Spreadsheet. The current event is plotted on the extreme left part of the plot. The plot shows that the current event has the lowest spectral ratio, comparable to nearby earthquakes and explosions. The high spectral ratios, indicating more low frequency content, were observed for a group of marine explosions. Mousing on the *Done* button in this display removes the plot window and returns control to the selection window, where the user can continue to select and view other plots.

RESULTS BY DISTANCE displays spectral ratio data as a function of the event-to-station distance. Mousing on this option in the **VIEW** menu displays the same region selection window as that described for ARDISPLAY in Section 7.3.1.2. After the regions have been selected, a plot selection window, similar to the one described above for the *PLOT BY REGION* display. An example of the spectral-ratio data plotted as a function of distance is shown below:
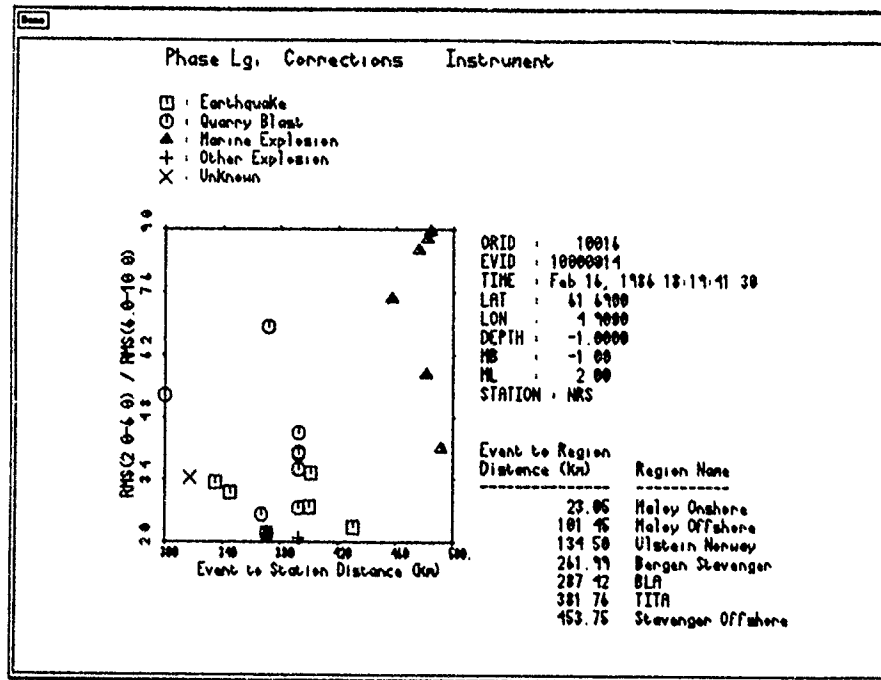
This plot uses the same symbols and color co.'es as the **PLOT BY REGION** display. The CURRENT EVENT is plotted as the asterisk, at about 370 km. The plot shows that the higher spectral ratios obse₁.ed for the underwater blasts might be related to their being at greater distance. Pressing the **Done** button removes the plot and returns control to the plot selection window, where additional plots can be selected.

7.3.2.3 SELECT Menu Options

The **SELECT** menu options allow the user to set up parameters for computing spectral ratios which are displayed in the **VIEW** functions, described above.
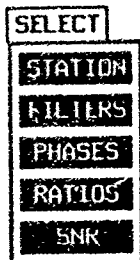
STATION brings up a check box window for selecting stations for which spectral data is available for computing spectral ratios. This display is the same as that described in Section 7.2.1.3.
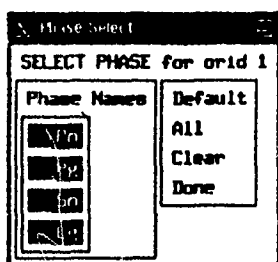
PHASE causes a subwindow to be displayed for selecting phases for which spectra are available. Mousing on the check boxes to the left of each phase name will include that phase in the spectral ratio calculation. The **Default** is for *Pn*, *Pg*, *Sn*, and *Lg* to be selected. **All** selects all the phases on the list. **Clear** removes all selections. **Done** causes the selection subwindow to be removed.

RATIOS causes a subwindow to be displayed for specifying the specific ratios to be computed. Selecting this option displays the following window:
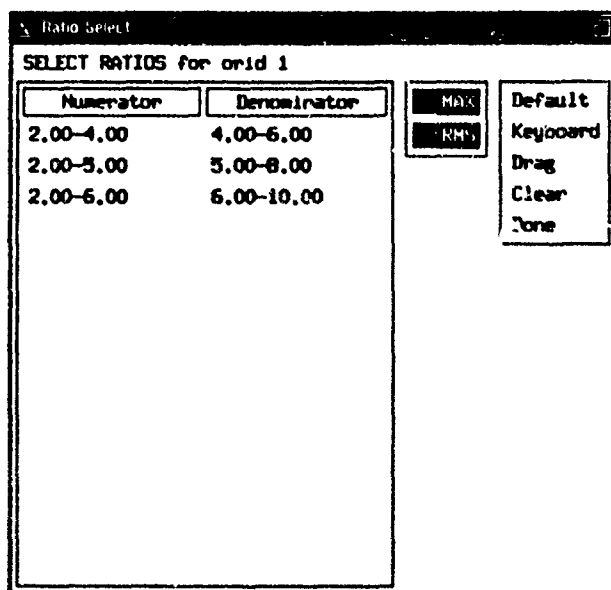
This window shows the default frequency bins for the numerator and denominator in computing the spectral ratios and are selected if the **Default** button is moused. Additional ratios can be defined in two ways. In the first method, **Keyboard**, entries can be made on the keyboard in a special subwindow, shown below:

By selecting on *Numerator* or *Denominator*, typing in the limiting spectral-bin frequencies, and mousing on the *Enter* button, the defined bin specifications appear in the *SELECT RATIO* window, as shown. If *Drag* is selected, the bins can be selected by dragging the desired bins on the spectra themselves, as shown below:

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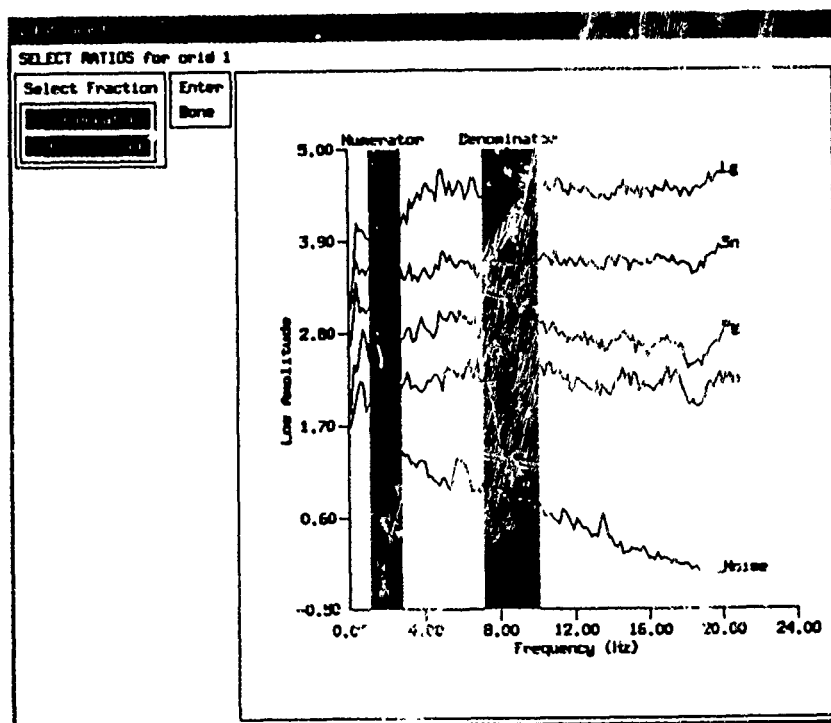
Again, the check boxes in the upper left are used to select the *Numerator* or *Denominator*, the drag is made, resulting in the bins being darkened-in and labeled, and then mousing on *Enter* causes the bin frequencies to be entered into the *RATIO SELECT* box, as shown below:


```
Ratio Select                                    ⊡

SELECT RATIOS for orid 1

 ┌──────────────┬──────────────┐  ┌──────┐  ┌──────────┐
 │  Numerator   │ Denominator  │  │■ MAX │  │ Default  │
 ├──────────────┼──────────────┤  │■ RMS │  │ Keyboard │
 │ 2.00-4.00    │ 4.00-6.00    │  └──────┘  │ Drag     │
 │ 2.00-5.00    │ 5.00-8.00    │            │ Clear    │
 │ 2.00-6.00    │ 6.00-10.00   │            │ Done     │
 │ 1.50-3.50    │ 7.70-15.23   │            └──────────┘
 │ 1.07-2.77    │ 7.15-10.08   │
 │              │              │
 │              │              │
 └──────────────┴──────────────┘
```

CORRECT is the option for defining corrections to be made to the spectra before computing spectral ratios. Choosing this option displays a subwindow containing check boxes for defining corrections, shown below:


```
Spectral Correction Parameters                  ⅃

SELECT CORRECTION PARAMETERS for orid 1
                                    YES  NO
 ┌─────────────────────────────────┬────┬────┐
 │ Remove Noise                    │ □  │ ■  │
 │ Remove Instrument Response      │ □  │ ■  │
 │ Remove Q                        │ ■  │ □  │
 └─────────────────────────────────┴────┴────┘

 Nearest Region = TITA

 Q0:   [325.00]      ┌─────┐  ┌──────────┐
 zeta: [0.48]        │■ Pn │  │ Path     │
 f0:   [1.00]        │■ Pg │  │ Default  │
 gvel: [8.10]        │■ Sn │  │ Enter    │
 dist: [392.18]      │■ Lg │  │ Done     │
                     └─────┘  └──────────┘
```

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If *Remove Noise* is selected, then the noise-spectra values are subtracted frequency-by-frequency from each of the signal spectra values. *Remove Instrument Response* causes the instrument response to be deconvolved from the spectrum. If *Remove Q* is selected, then the Q correction must be defined in the lower box. Values for Qo, the frequency-dependent term, *zeta*, and the reference frequency, *fo*, can be entered by typing them in. Alternatively, *Path* can be moused and values stored in the database for the nearest reference region, for the selected station, will be entered in for the selected phase in the check box. *Enter* must be pressed after selecting the phase and pressing *Path* for each phase. If *Default* is moused, the same default values are entered for all phases. The values for group velocity, *gvel*, and distance, *dist*, are entered automatically. Pressing *Done* closes out the *SELECT CORRECTION* window and the selected corrections will be made to the spectra before the spectral ratios are computed.

Note: These corrections are only made for the purposes of computing spectral ratios and the corrected spectra are **not** permanently stored in the database. The FSDISPLAY interface, described in Section 7.2.2, should be used to store corrected spectra.

7.3.2.4 EXECUTE Menu Options
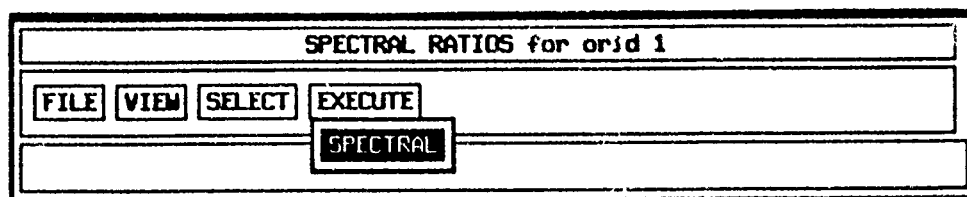
The single option under **EXECUTE, *SPECTRA*,** initiates a process that computes the spectral ratios selected. The *SPECTRA* option remains displayed until the process has completed.

7.3.3 Multiple Event Recognition System (MERSY)

The Multiple Event Recognition System (MERSY) program identifies spectral modulations, or scalloping, which appears to be time independent and, therefore, a possible indication of multiple events, or ripple-fire. MERSY compares spectra for different phases associated with an

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event and determines if spectral scalloping is present in two or more spectra. MERSY is designed to be run as part of the *Ripple-Fire* discriminant and is run when the *Ripple-Fire* discriminant is executed. The MERSYdpy, or MERSY display program, is the user interface which provides explanations for the results of MERSY processing itself.

MERSY computes power cepstra, which are forward Fourier transforms of the amplitude spectra, for all phases associated with the event, as well as the noise background to the first-arrival phase. A peak-picking algorithm then identifies significant peaks in each of the cepstra, which may be an indication of spectral scalloping. If cepstral peaks are found in two or more phases, but not in the noise, then it is determined that the spectral modulation is time independent, which indicates that the event is a ripple-fired explosion. In addition to identifying cepstral peaks, MERSY also measures features on the spectra and cepstra, including spectral and cepstral variance and the spectral signal-to-noise ratio. These features are then stored in the database and are analyzed by the CLIPS rules.

In applying MERSY to an event, it is assumed that spectra have been previously computed for the event. The FSDISPLAY program, described in Section 7.2.2, can be used to compute spectra. The spectra should not have any corrections applied. MERSY itself applies an instrument correction. MERSYdpy provides plots of spectra and cepstra, which indicates which peaks have been identified as significant and consistent, and a textual explanation of the results.

The MERSYdpy function can be initiated either from the **PROCESS** menu option of the Spreadsheet or from any of the summary display windows for the *Ripple-Fire* discriminant. When this process is initiated for a selected current event, a subwindow is created which contains the MERSYdpy menubar, which has the standard menus discussed in Section 7.1.

7.3.3.1 FILE Menu Options

This menu is exactly the same as that for the ARDISPLAY function (see Section 7.3.1.1). Currently, the only option which has been implemented is *QUIT*, which exits the MERSYdpy process and returns control to the Spreadsheet.

7.3.3.2 **VIEW Menu Options**

The **VIEW** menu has options for the user to view spectra, cepstra, and explanations of the results of MERSY processing.
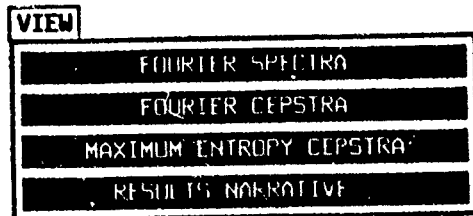
FOURIER SPECTRA brings up a subwindow which displays on the same axis all the spectra computed for the event. The spectra displayed have been corrected for instrument. The example below shows an event which has strong spectral modulation in three phases which is not apparent in the noise:
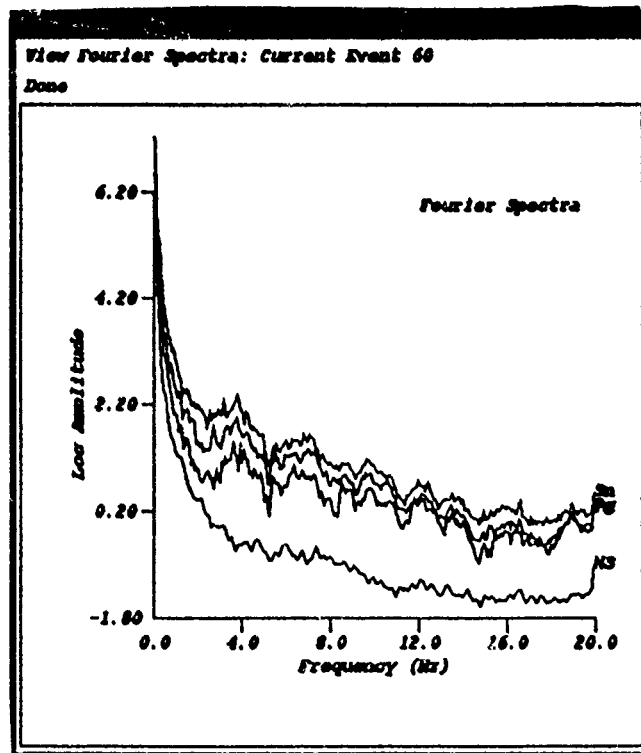
FOURIER CEPSTRA displays in a subwindow of the powei cepstra, which are the Fourier transforms of the amplitude spectra. The cepstra are displayed on the same axis and are labeled for the phases they correspond to. Vertical lines indicate the cepstral peaks which have been identified as significant and not present in the noise cepstra, which is an indication of time

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independent spectral scalloping. Cepstra for the spectra shown above are shown below, which have two significant peaks:
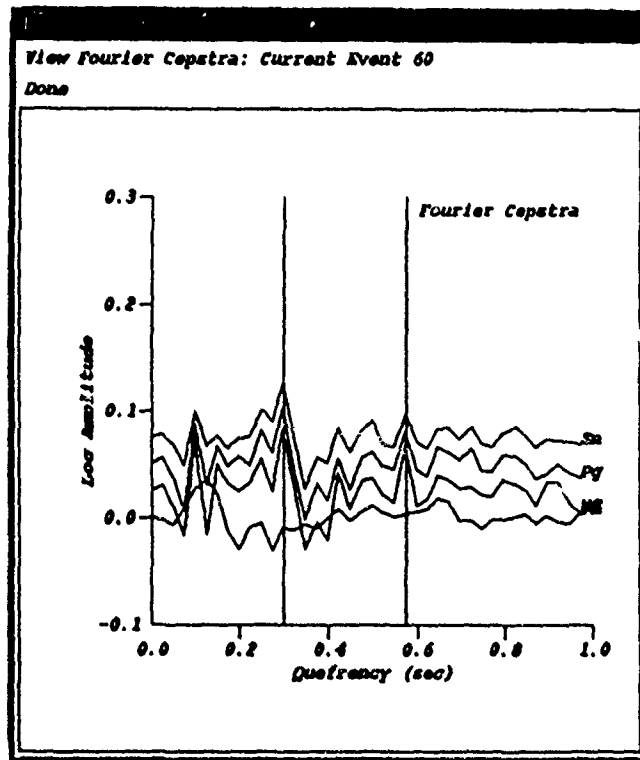
MAXIMUM ENTROPY CEPSTRA shows the cepstra computed by a maximum entropy estimation algorithm. This algorithm reduces the variance of the cepstra and tries to make the peaks sharper. These cepstra are displayed in the same way as the Fourier cepstra. Examples for the event above are shown below:
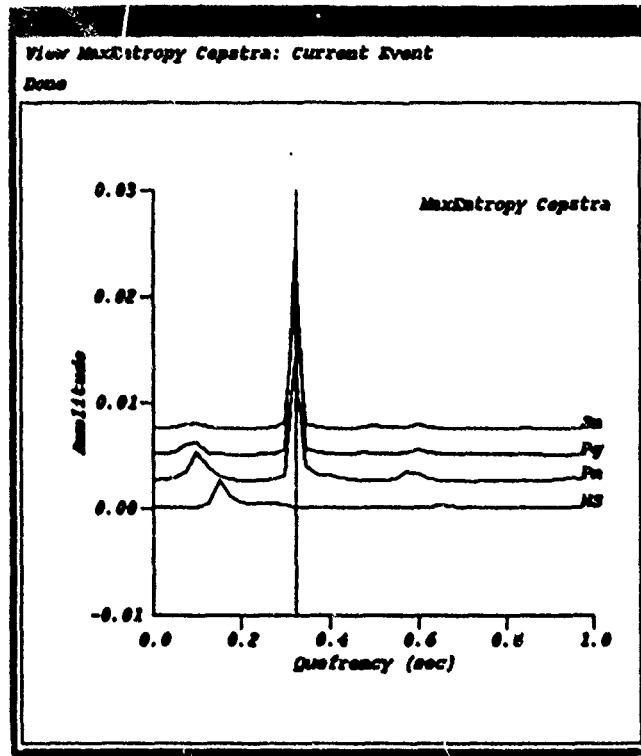
RESULTS NARRATIVE brings up a subwindow which gives a textual explanation of the results, in terms of how many peaks were found and values of the spectral snr and spectra and cepstral variances, as shown below:

Done

MERSY EXPLANATION

NRS

Origin ID 60

Mersy results indicate event does have ripple fire
2 consistent FFT cepstral peaks
1 consistent Max Entropy cepstral peaks, and
-4.298779 FFT cepstral variance of last phase

Number of phases identified = 3

STATISTICS

Arrival Idn	Spectral SNR db	Log Variance Detrended Spectra	Log FFT Cepstral Variance
Pn 5285	8.301941	-1.252941	-3.995303
Pg 5286	11.116906	-1.397201	-4.139401
Sn 5287	11.156453	-1.558108	-4.298779

Fourier Cepstral peak ripple fire delay estimate (sec) :
0.300000 0.575638

MaxEntropy Cepstral peak ripple fire delay estimate (sec) :
0.325000

7.3.3.3 SELECT Menu Options

The **SELECT** menu currently has only two options. *STATION* brings up a check box window for selecting the station to display MERSY results. This display is the same as that described in Section 7.2.1.3.

CEPSTRAL PEAKS is an option which allows the user to examine the cepstra and select peaks if they have not been automatically picked by MERSY. This option produces the following window:

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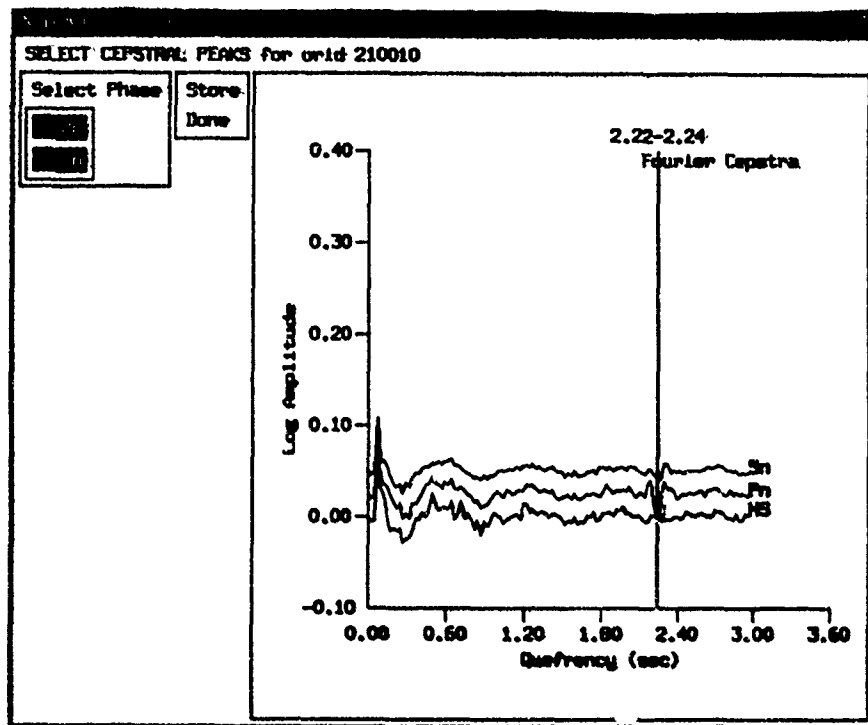
This display shows the Fourier cepstra for each of the phases and any of the cepstral peaks identified by MERSY will be indicated by a vertical line. The user can manually select any other peaks in the cepstra by first selecting the phase in the check boxes in the *Select Phase* window and then using the mouse to drag, with the left mouse button depressed, across the peak. The area selected is then darkened-in, and the frequency range selected is printed above the area. When the *Store* button is pushed with the mouse, the cepstral amplitude and frequency of the peak is found in the area and stored in the database for the phases selected. Mousing on the *Done* button removes the display and returns back to the MERSY top level.

Note: When the peaks are selected in this way, they are stored only for the phases which are selected in the *Select Phase* window. It is assumed that the user has checked to make sure no such peak is present in the noise cepstra, which is the one labeled NS.

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7.3.4 Dynamic Time Warp (DTW)

The DTW program matches the incoherent-beam templates of an event with those of reference events. The comparison is accomplished by lining up the incoherent beams of reference events and the current event on identified phases, deforming the time axis of the reference event to make it match that of the current event, and then to compute the distance of separation between current event and the deformed reference event. If the incoherent beams are very similar and nearly overlap, the separation distance will be very small.

The Dynamic Time Warp algorithm utilizes an algorithm, called dynamic programing, to deform or "warp" the time axis of the reference event templates to match those of the current event. The goal of this algorithm is to determine if the coda shapes of the current event templates are similar or dissimilar to those of reference events. The time-warping is done in order to match events which may lie at slightly different distances from the array, and thus, the relative arrival times of the different phases may be different. Thus, shape differences due to differences in relative arrival times of phases for events at different distances are reduced by the time-warping. The DTW algorithm is quite involved and the reader is referred to the references in Section 1.1 for details.

DTW assumes that incoherent beams have been computed for the current event and reference events in the closest reference region. The incoherent beams for the current and reference events must have been made in the same filter bands. Furthermore, it is necessary that both a starting phase and stopping phase be defined on both the current and reference event templates. The duration of the stopping phase, which is usually Lg, is critical, since the durations must be determined consistently for reference and current event for the DTW matches to be meaningful. DTW lines up the incoherent beams in time on the first arrival (usually Pn) and lines the templates up vertically on the peak amplitudes in the incoherent beams.

There are currently two interfaces provided to the user in DTW: DTW Setup display, or DTWDisplay, and the DTW Results display, or DTWVws. The Setup interface allows the user to set various parameters in the DTW algorithm and to run the process interactively. DTWVws shows the results of previous runs. The *DTW* discriminant in the Spreadsheet runs the DTW algorithm itself, although it can also be run interactively, either from the **PROCESS** menu in the Spreadsheet or from the results summaries displays for the *DTW* discriminant. DTWVws can be

started from DTW, from the **VIEW** menu, or it can also be started up directly from the **PROCESS** menu or from any of the results summaries for the *DTW* discriminant.

In the next two sections, we first describe the DTWDisplay Setup interface and then the DTWVws interface.

7.3.4.1 DTWDisplay Setup Menus

This section describes the DTWDisplay Setup interface. As mentioned above, it allows the user to setup and run DTW interactively. Also, the results of DTW processing can be displayed. The details of this display process, or the DTWVws interface, will be discussed in the next section. The DTWDisplay interface function can be initiated from the **PROCESS** menu option of the Spreadsheet or from any of any of the summary display windows for the *DTW* discriminant. When this process is initiated for a selected current event, a subwindow is created which contains the DTWDisplay Setup menubar, which has the standard menus discussed in Section 7.1.

7.3.4.1.1 FILE Menu Options

The **FILE** menu is identical to that of the ARDISPLAY function (see Section 7.3.1.1). Currently, the only option which has been implemented is *QUIT*, which exits the DTW process and returns control to the Spreadsheet.

7.3.4.1.2 VIEW Menu Options

The **VIEW** menu has options for the user to view the incoherent beam templates and the results of DTW processing.
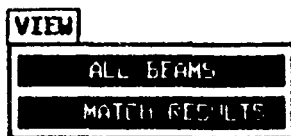
ALL BEAMS is the **VIEW** option in DTW which plots all the incoherent beams which have been computed for the current event. This display is the same as the *VIEW BEAMS* option of FSDISPLAY, discussed in Section 7.2.2.2.

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MATCH RESULT initiates the DTWVws function, which displays the results of DTW processing. Mousing on this option replaces the DTW Setup display with the DTW Results display and its associated menubar. The details of this display are discussed in Section 7.3.4.2.

7.3.4.1.3 SELECT Menu Options

The *SELECT* menu options allow the user to set up parameters for interactively running the DTW process.
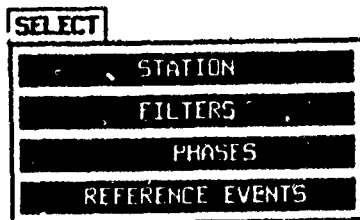
SELECT
STATION
FILTERS
PHASES
REFERENCE EVENTS

STATION brings up a check box window for selecting the stations for which incoherent beam data is available and to apply the DTW matcher. This display is the same as that described in Section 7.2.1.3.

FILTERS displays a window containing check boxes for all the filter frequency bands for which incoherent beams have been computed and on which the DTW match will be applied. This window is identical to the one described for IBEAM in Section 7.2.1.3.

PHASES displays a subwindow which allows the user to select phase regions on incoherent beams. Only the incoherent beams selected in *FILTERS* are displayed. An example of four selected phase regions for a single incoherent beam (8 to 16 Hz) is shown below:
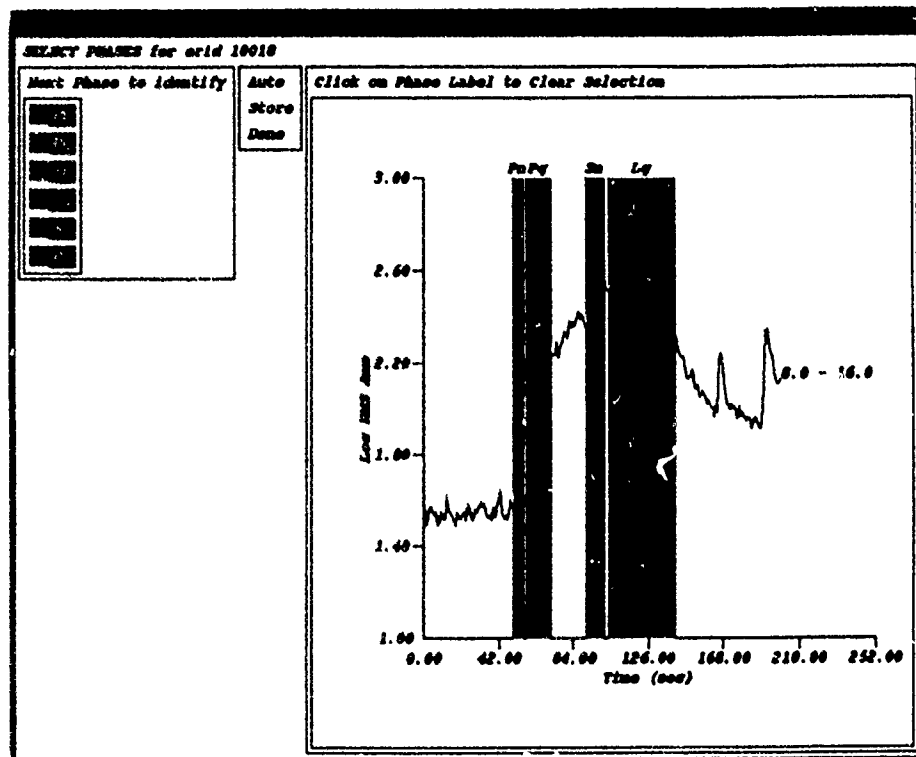
These selections are important because they set the limits which will be used to define the template to DTW. The starting point will be the first point of the *Pn* window. The ending point will be the last point of the *Lg* window. In order for the DTW analysis to be meaningful, it is important that these region selections are made as consistently as possible.
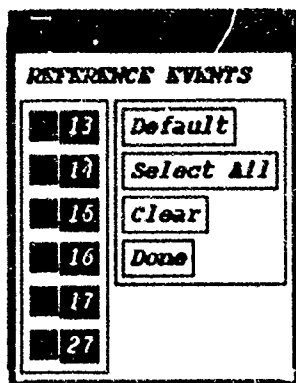
REFERENCE EVENTS brings up the check boxes shown to the left. When this option is selected, DTW finds the closest reference region to the current event. All the reference events in that region are defined as possible reference events. The numbers shown in the window are the origin ids (orids) for the events in the reference region. Mousing on the boxes selects or deselects reference events to be matched against the current event. Buttons are also available for selecting a *Default* (the last orid), *Select All* to select all the reference events, *Clear* to remove all selections, and *Done* to set the selections and remove the selection window.

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7.3.4.1.4 EXECUTE Menu Options

The **EXECUTE** menu options actually execute the DTW process.

```
EXECUTE
   SELECTIONS
   AUTOMATIC DEFAULTS
```
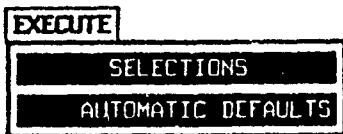
SELECTIONS causes DTW to be applied to the events which have been selected in the DTWDisplay setup interface.

AUTOMATIC DEFAULTS causes DTW to be applied to default reference events and filters. These are the same default values which are used in the routine processing of the *DTW* discriminant.

7.3.4.2 DTWVws Results Display Menus

This section describes the DTWVws Results display interface. This process is initiated when the *MATCH RESULTS* option is selected in the **VIEW** menu. It can also be directly invoked from the **PROCESS** menu in the Spreadsheet or from any of the summary display windows for the *DTW* discriminant. When this process is initiated for a selected current event, a subwindow is created which contains the DTWVws menubar, which has the standard menus discussed in Section 7.1.

7.3.4.2.1 FILE Menu Options

The **FILE** menu is identical to that of the ARDISPLAY function (see Section 7.3.1.1). Currently, the only option which has been implemented is *QUIT*, which exits the DTW process and returns control to the Spreadsheet.

7.3.4.2.2 VIEW Menu Options

The **VIEW** menu contains all the options for actually displaying the results of DTW processing on the current.

RESULTS BY SEPARATION shows plots of the DTW match cumulative distance as a function of the separation of the reference events from the current event. Distance in this case is in units of km. An example of the display is shown below:
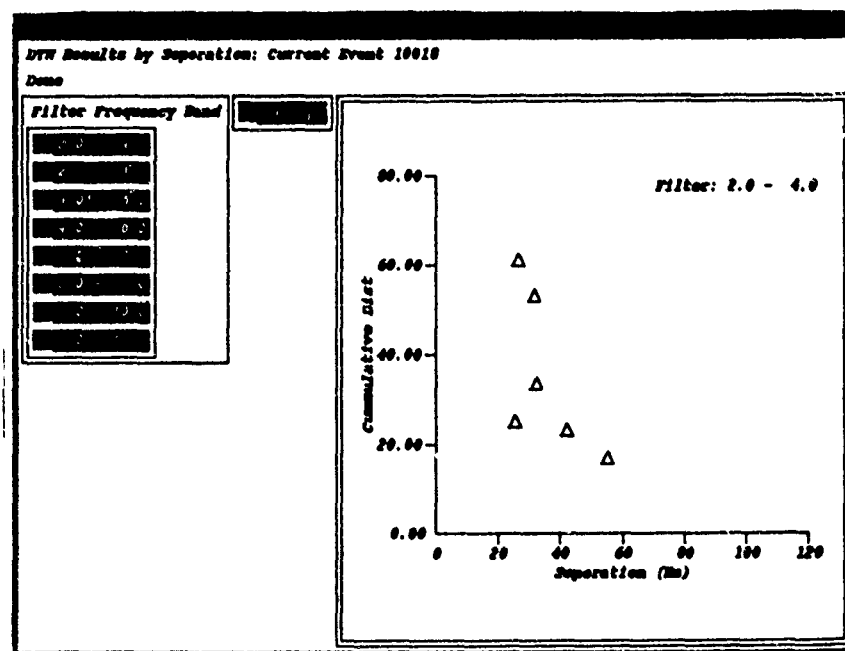
The window on the left lists the filters which have been matched to the current event. Mousing on the check boxes to the left of the filter band frequencies selects that filter for display. The window on the right shows the actual plot of the DTW distances versus distance. Low values of these distances indicate that the events match well. The symbols are coded to the event type. In this case, triangles are earthquakes and all the reference events were earthquakes. This plot changes when the filter selection is changed in the left window. Mousing on the **Done** button removes the display.

DISPLAY BY SIMILARITY plots the incoherent beam templates on the same axis in order of how similar they are, as shown below:

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DTW Results by Similarity: Current Event 10018
Displays beams stacked according to how well they match
Done

Filter Frequency Band

2.0 - 4.0
2.5 - 4.5
3.0 - 5.0
4.0 - 6.0
5.0 - 7.0
6.0 - 8.0
8.0 - 10.0
8.0 - 16.0

Filter: 8.0 - 16.0
ORID - Acc Distance

16 -19.4
27 -14.8
15 -12.1
14 -10.2
12 -10.0
10018

Relative Log RMS Amplitude
Time (sec)
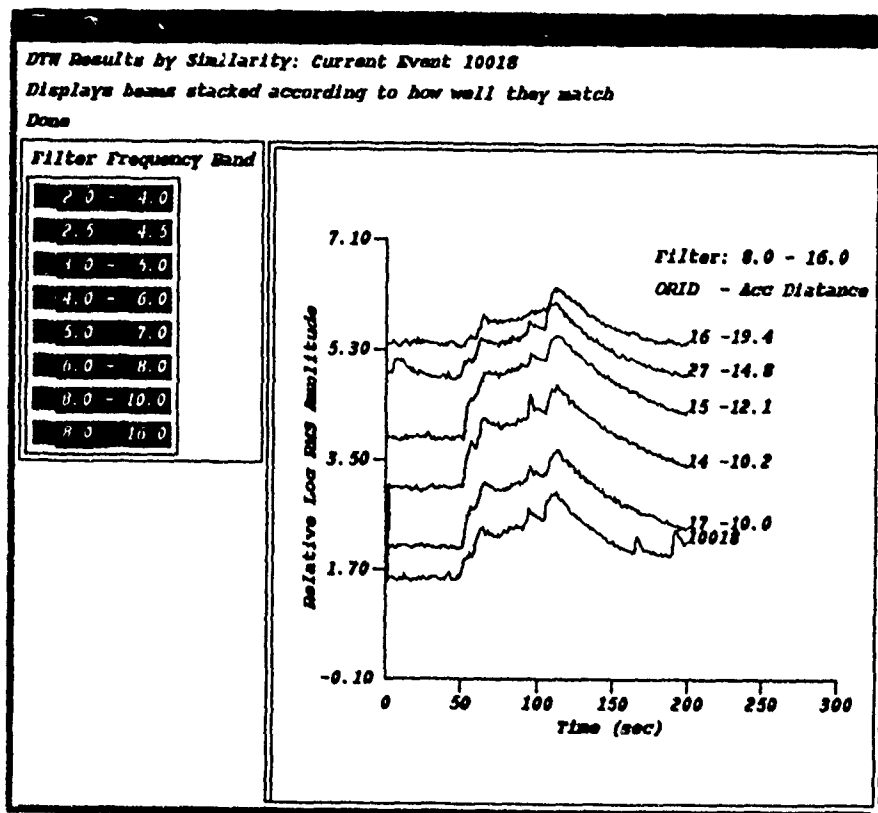
The window on the left has check boxes for changing the filter band. The window on the right displays the actual incoherent beams. The current event incoherent beam is plotted at the bottom (orid 10018). The reference events are plotted above the current event in order of how well they matched. Templates which matched best are plotted immediately above the current event, whereas those which matched less well are plotted farther away. The accumulated distances of match are shown to the right of each plot, under the column heading *Acc Distance*. Mousing on the check boxes in the window to the left, to select a different filter, will automatically change the display on the right to the selected filter. Mousing on the *Done* button removes the display.

MATCHED PAIR shows a comparison of the current event template with any reference event template in any frequency band. One example is shown below:

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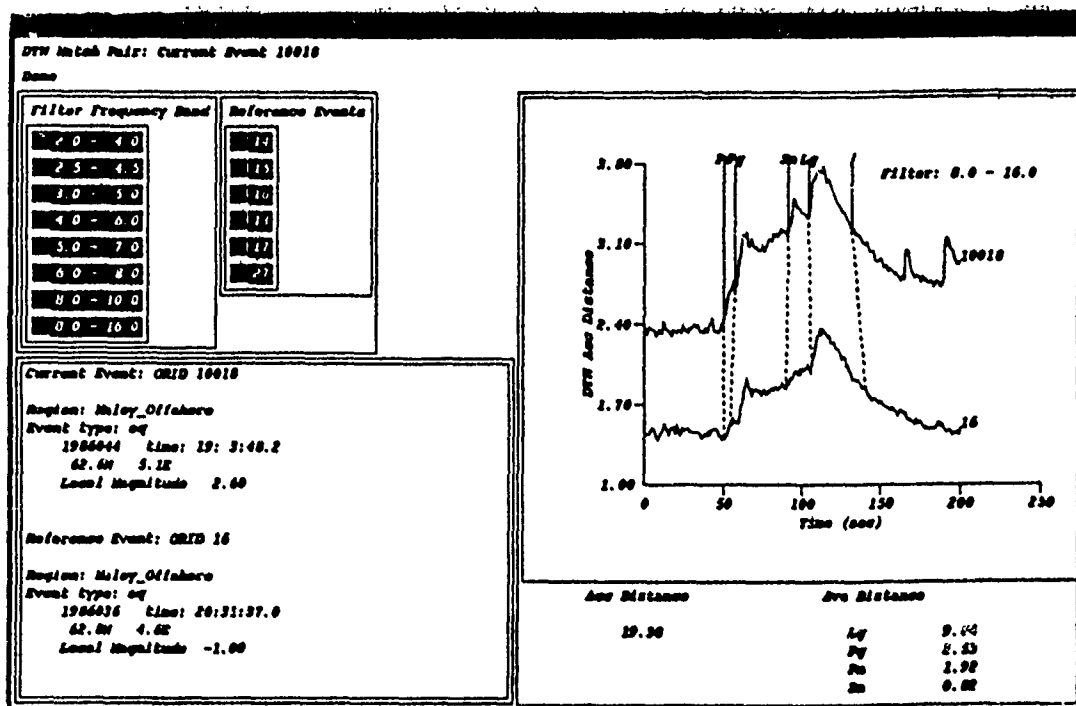
This display has four subwindows. The windows labeled *Filter Frequency Band* and *Reference Events* contain check boxes which allow the filter bands of the matched pair and the selected reference event to be changed. The window displayed below these windows has source parameter information about the current and selected reference event. The window on the right contains the two templates. The current event template is plotted above the reference event. The dashed lines indicate how the starting points of each phase region and the last point, labeled *l*, were matched by the time warper. Below the plot, the *Acc Distance* gives the DTW separation between two events, and *Ave Distance* gives the average separation in each stapick phase interval between the two events. This display is removed by mousing on the *Done* button.

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7.3.4.2.3 SELECT Menu Options

The **SELECT** menu options select stations and reference events to be displayed.

```
SELECT
     STATION
  REFERENCE EVENTS
```

STATION selects the station for which to display DTW results. This option is the same as that described in Section 7.2.1.3.

REFERENCE EVENTS selects the reference events for the display. This option is the same as the **REFERENCE EVENTS** selection option of DTWDisplay, described in Section 7.3.4.1.3.

7.4 MISCELLANEOUS SIGNAL ANALYSIS RESEARCH FUNCTIONS

ISEIS has three processes provided for research purposes. Continuous spectra (CFSDISPLAY), or sonogram, computes and displays multiple power spectra in a two dimensional form, i.e., signal power as a function of frequency and time. Continuous frequency-wavenumber (FK) analysis (CFKDISPLAY) computes and displays multiple FK estimates on a time-series in the form of a template of FK coherence, velocity and azimuth as a function of time. COMPÁRE is a function which allows the user to interactively overlay waveforms and visually compare them.

7.4.1 Continuous Fourier Spectra (CFSDISPLAY)

CFSDISPLAY provides the user interface for setting up the input to the process to compute and store continuous spectra, or sonograms, executing the process, and viewing the results.

Sonograms are generated by computing spectra for windowed waveforms where the windows are moved by user-specified time increments down the entire seismogram trace. The spectra are then combined together to display a contour plot of spectral power as a function of time and frequency. Each of the spectra are computed in exactly the same way as single spectra, computed with the FSDISPLAY function, which is described in Section 7.2.2. Thus, for array data, the sonograms can be computed from channel-averaged spectra. Moreover, all the same correction options in FSDISPLAY, including instrument, source, and noise corrections, can be

made in the sonogram process, although it is usually best to view sonograms with no corrections. The user interface for setting up the process is very similar to that for FSDISPLAY. The additional parameters which must be defined include the window time shifts and the time interval for which sonograms are to be computed.

The CFSDISPLAY process for setting up and executing the continuous spectrum process is invoked from the Spreadsheet **PROCESS** (see Section 5.4.5) menu by mousing on the option *SONOGRAM*. This process is initiated on a single event, selected from the Spreadsheet.

When the CFSDISPLAY process is initiated for a selected current event, a subwindow is created containing the CFSDISPLAY menubar, which has the standard menus discussed above in Section 7.1.

7.4.1.1 FILE Menu Options

This menu is exactly the same as that for the IBEAM and FSDISPLAY functions (see Section 7.2.1.1). Currently, the only option which has been implemented is *QUIT*, which exits the CFSDISPLAY process and returns control to the Spreadsheet.

7.4.1.2 VIEW Menu Options

The **VIEW** options allow the user to preview raw waveforms and to access the function to view previously computed sonograms.

TIME-SERIES displays a subwindow which allows the user to review the waveforms prior to computing spectra. This interface is useful for determining if any of the waveform channels have defective data and should be deleted. This interface is identical to that in the FSDISPLAY interface, which is explained in Section 7.2.2.2.

CFS PLOTS displays a new window which has its own menubar, as shown below:

```
⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
 ⎓ cfsplot                                              ▣
⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
        VIEW CONTINUOUS FOURIER SPECTRA for orid 10011
⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
  [FILE] [VIEW]
  [QUIT]
```
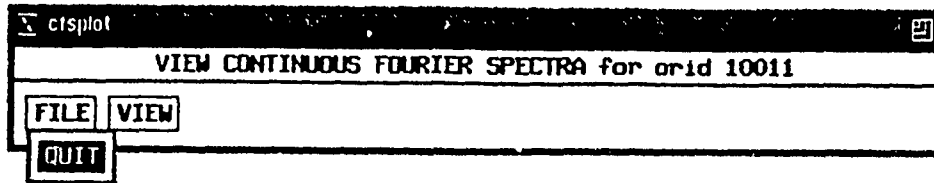
This menubar has two menus, **FILE** and **VIEW.** **FILE** has an option, *QUIT*, as shown above, which removes the window and returns control to the top level CFSDISPLAY interface. **VIEW** has three options, as shown below:

```
⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
        VIEW CONTINUOUS FOURIER SPECTRA for orid 10011
⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
  [FILE] [VIEW]
         [DORE PLOT]
         [CONTOUR PLOT]
         [MESH PLOT]
```
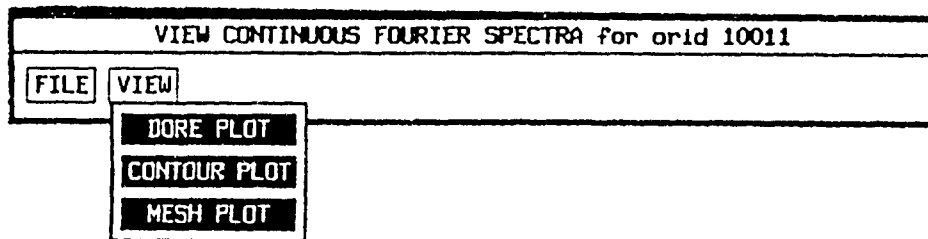
The *DORE* option executes the Shaded Sonogram program on the Stardent computer. This program provides a dynamic viewing capability which is possible in real time on the Stardent platform. The user can rotate, twist, zoom and pan the sonogram image. Colors can be changed in the display by using the RGB color editor. A pick capability is also provided so that a user can query the values of individual points on the sonogram surface. The user performs a viewing transformation by selecting the desired **ORBIT, PAN, ZOOM, TWIST,** and **DEFAULT** option from the **VIEW** menu and then dragging the mouse. Mouse drags have the following effects:

1. **ORBIT** - A drag from top to bottom causes the image to rotate toward the user and a drag from bottom to top causes the image to rotate away from the user. Side-to-side or diagonal drags work in a similar fashion. In general, the object tends to rotate with the mouse in an intuitive way.

2. **PAN** - The object follows the mouse as it is moved around. Care should be taken since the PAN function is a very sensitive, and it is easy to PAN the object off of the screen.

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3.   **ZOOM** - Top-to-Bottom mouse drags result in image enlargement, whereas opposite drags cause the image to get smaller.

4.   **TWIST** - A left-to-right drag at the bottom of the graphics window cause the object to twist in a clockwise direction and a right-to-left drag causes the opposite to occur. It is important to drag near the bottom of the graphics window.

5.   **DEFAULT** - The **DEFAULT** selection is used to restore the viewing parameters to their initial startup values. This function is useful if the user gets lost while ORBITING, PANNING and ZOOMING.

Note: The *DORE* option uses specialized Stardent graphics software, and thus, this option is only available when the Stardent hardware is available to the system.

CONTOUR PLOT is currently inactive. It is intended in the future to display a contour line plot of the sonogram.

MESH PLOT displays a wire mesh type plot of the sonogram, as shown below:
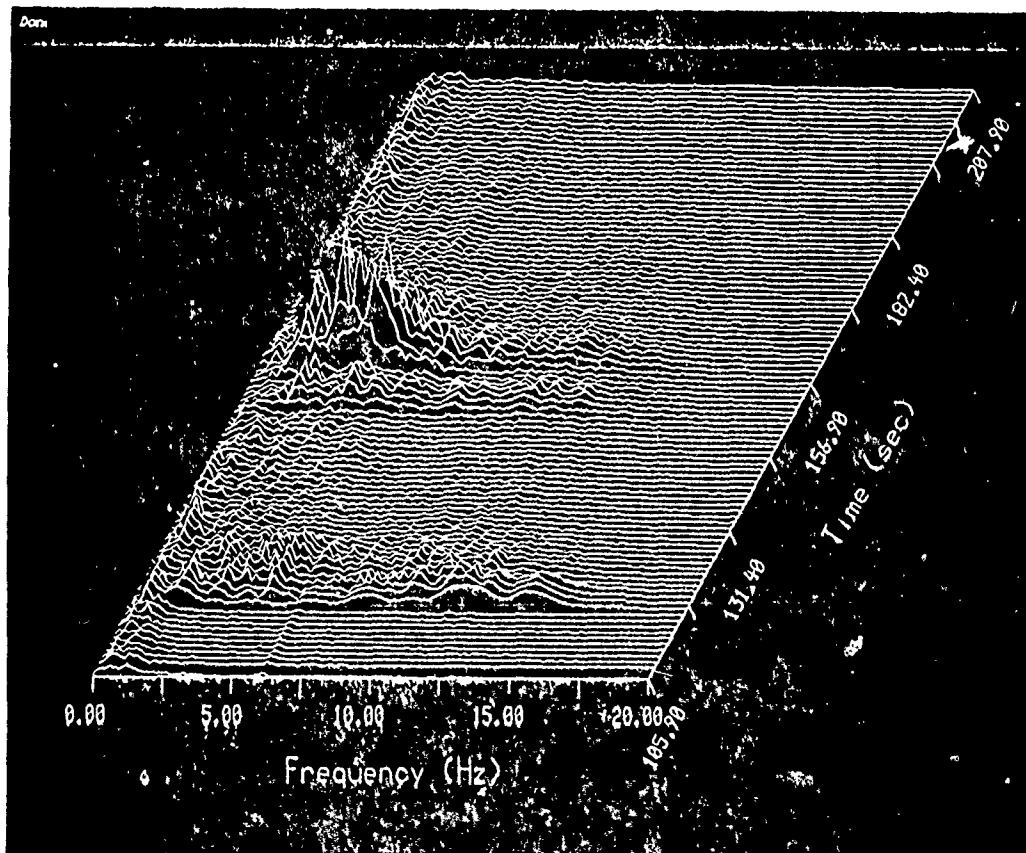
The wire mesh plot can be removed by mousing on the *Done* button.

7.4.1.3 SELECT Menu Options

The **SELECT** menu has options for controlling the input parameters to the CFSDISPLAY process.

STATION brings up a window listing all the stations for which waveform data is available for the event. This display is the same as that described in Section 7.2.1.3.

CHANNELS displays a scrollable window containing check boxes for all the channels available for the station. This display is the same as that described in Section 7.2.1.3.

TIME RANGE is used to set the limits on the time range for which to compute the sonogram. Selecting this option displays the subwindow shown below:

This window has text boxes for entering parameters for sonogram computation. NUMBER OF POINTS PER WINDOW is the number of points to Fourier transform in a single window; NUMBER OF POINTS TO SHIFT is how much to shift each window as it is moved down the seismograms; SIGNAL START POINT is the number of points from the beginning of the seismogram for the signal; NOISE START POINT is the beginning of the noise relative to the start of the seismogram; NUMBER OF SIGNAL POINTS TO PROCESS is the total length of the seismogram for which the sonogram is to be computed; and NUMBER OF NOISE POINTS TO PROCESS is the total length for the noise.

Note: The noise window is only transformed once. This noise spectrum is only used if the option for noise correction is selected.

The bottom button, labeled 'Click here to use drag for signal and noise correction,' is mouse-sensitive and brings up the following window:
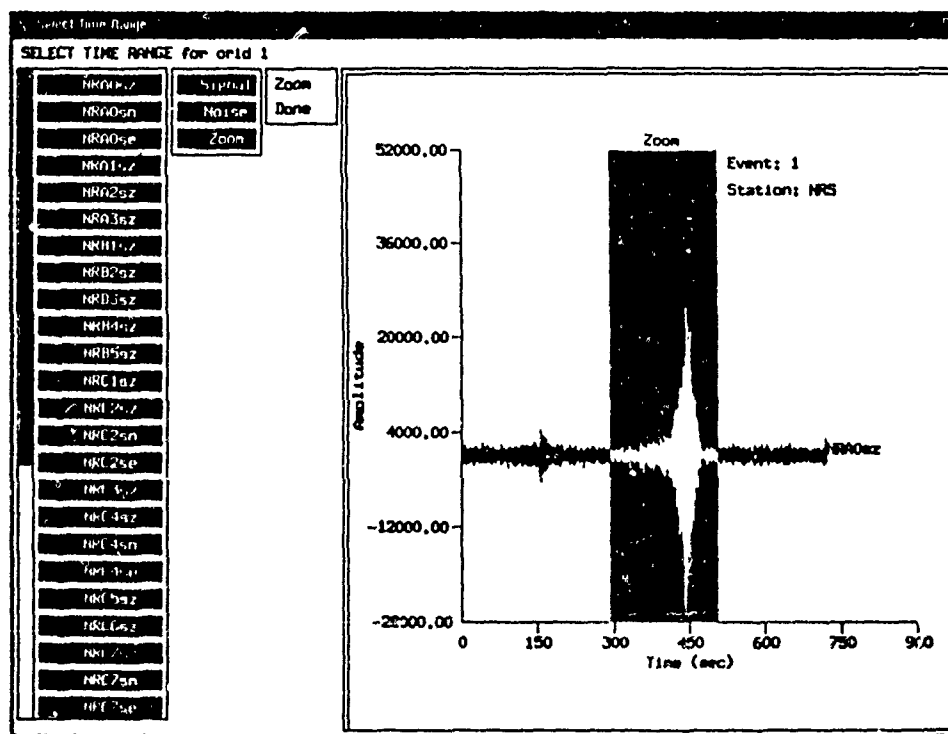
This window provides the capability for defining the noise and signal time intervals by mouse-dragging directly on a single-channel waveform. The check boxes on the left of this window can be used to select the channel waveform to display. The check boxes, labeled *Signal* and *Noise,* can be selected for dragging the time intervals for signal and noise using the left mouse button. The selected regions are then darkened-in, as shown below:

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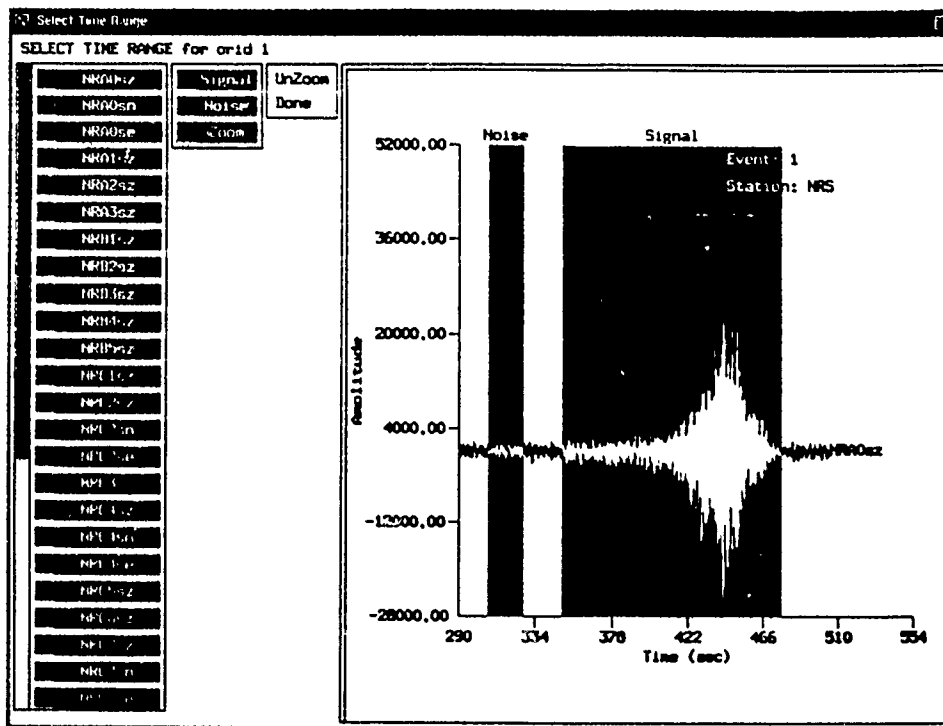
When the *Done* button is selected, the window is removed and the *Selected Time Parameters* is re-displayed with the appropriate values filled in, as shown below:

If the *SMOOTHING* option is selected, a subwindow is displayed to allow the user to select spectral smoothing parameters for each spectrum for the sonogram. This interface is identical to the *SMOOTHING* option in FSDISPLAY, described in Section 7.2.2.3.

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The *CORRECTION* option allows various corrections to be made to the spectra. The user selectable corrections include noise subtraction, using the noise spectrum defined in *TIME SELECT*, and deconvolution of the instrument response and the Von Seggern-Blandford explosion source model. This interface is identical the *CORRECTION* option in FSDISPLAY, described in Section 7.2.2.3.

7.4.1.4 EXECUTE Menu Options

```
┌─────────────────────────────────────────────────────────────┐
│  ┌─────────────────────────────────────────────────────────┐ │
│  │          CONTINUOUS FOURIER SPECTRA for orid 1          │ │
│  └─────────────────────────────────────────────────────────┘ │
│  ┌────┐ ┌────┐ ┌──────┐ ┌───────┐                            │
│  │FILE│ │VIEW│ │SELECT│ │EXECUTE│                            │
│  └────┘ └────┘ └──────┘ └───────┘                            │
│                     ┌──────────────────┐                     │
│                     │CONTINUOUS SPECTRA│                     │
│                     └──────────────────┘                     │
└─────────────────────────────────────────────────────────────┘
```
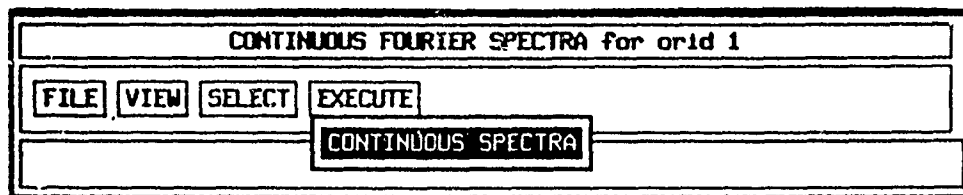
The single option under **EXECUTE** is *CONTINOUS SPECTRA*, which initiates the CFSDISPLAY process using the default or user selections. The continuous spectrum computation can take a long time to complete. Thus, selecting *CONTINUOUS SPECTRA* starts up a subprocess which runs in the background independently of CFSDISPLAY. The *CONTINOUS SPECTRA* option remains displayed until this process has begun. When this ends, a process display icon, discussed in Section 3.5, will be displayed which will be mouse-sensitive. This icon will be displayed in the upper right of the monitor, regardless of whether or not the original CFSDISPLAY process is still running. If the icon is moused, the *CFS PLOTS* process, which also runs under the **VIEW** menu, will be started, which can be used then to view the results.

7.4.2 Continuous Frequency-Wavenumber Analysis (CFKDISPLAY)

CFKDISPLAY provides the user interface for setting up the input to the process to compute and store continuous frequency-wavenumber (FK) spectra, executing the process, and viewing the results.

Continuous FK spectra are used to generate templates of signal coherency, represented by F-statistic, velocity, and azimuth as a function of time. CFKDISPLAY computes broadband FK spectra, where the user specifies the frequency band. The algorithm then computes broadband FK spectra in windows which are moved down the entire seismogram trace by user-specified time increments. The FK spectrum for each window is searched for the peak power and the F-statistic, velocity, and azimuth of the peak power is then determined and stored. CFKDISPLAY can then

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be used to display plots of the FK peak measurements, i.e., F-statistic, velocity, and azimuth, as a function of time. These templates can be studied to identify phases and to examine trends in the FK measurements which may be distinctive to events in different regions.

The CFKDISPLAY process is invoked from the Spreadsheet **PROCESS** (see Section 5.4.5) menu by mousing on the option *CONTINUOUS FK*. This process is initiated on a single event, selected from the Spreadsheet.

When the CFKDISPLAY process is initiated for a selected current event, a subwindow is created containing the CFKDISPLAY menubar, which has the standard menus discussed above in Section 7.1

7.4.2.1 FILE Menu Options

This menu is exactly the same as that for the IBEAM and FSDISPLAY functions (see Section 7.2.1.1). Currently, the only option which has been implemented is *QUIT*, which exits the CFKDISPLAY process and returns control to the Spreadsheet.

7.4.2.2 VIEW Menu Options

The VIFW options allow the user to preview raw waveforms and to access the function to view previously computed FK templates.

TIME-SERIES displays a subwindow which allows the user to review the waveforms prior to computing FK spectra. This interface is useful for determining if any of the waveform channels have defective data and should be deleted. This interface is identical to that in the FSDISPLAY interface, which is explained in Section 7.2.2.2.

CFK PLOTS displays another window with a new menubar, which is identical to the *CFS PLOTS* display produced by CFSDISPLAY (see Section 7.4.1.2). This menubar has two menus, FILE and VIEW. FILE has a single option, *QUIT*, which removes the window and

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returns control to the top level CFKDISPLAY interface. **VIEW** also has a single option, **TEMPLATES**, which, when selected, displays the following group of windows:
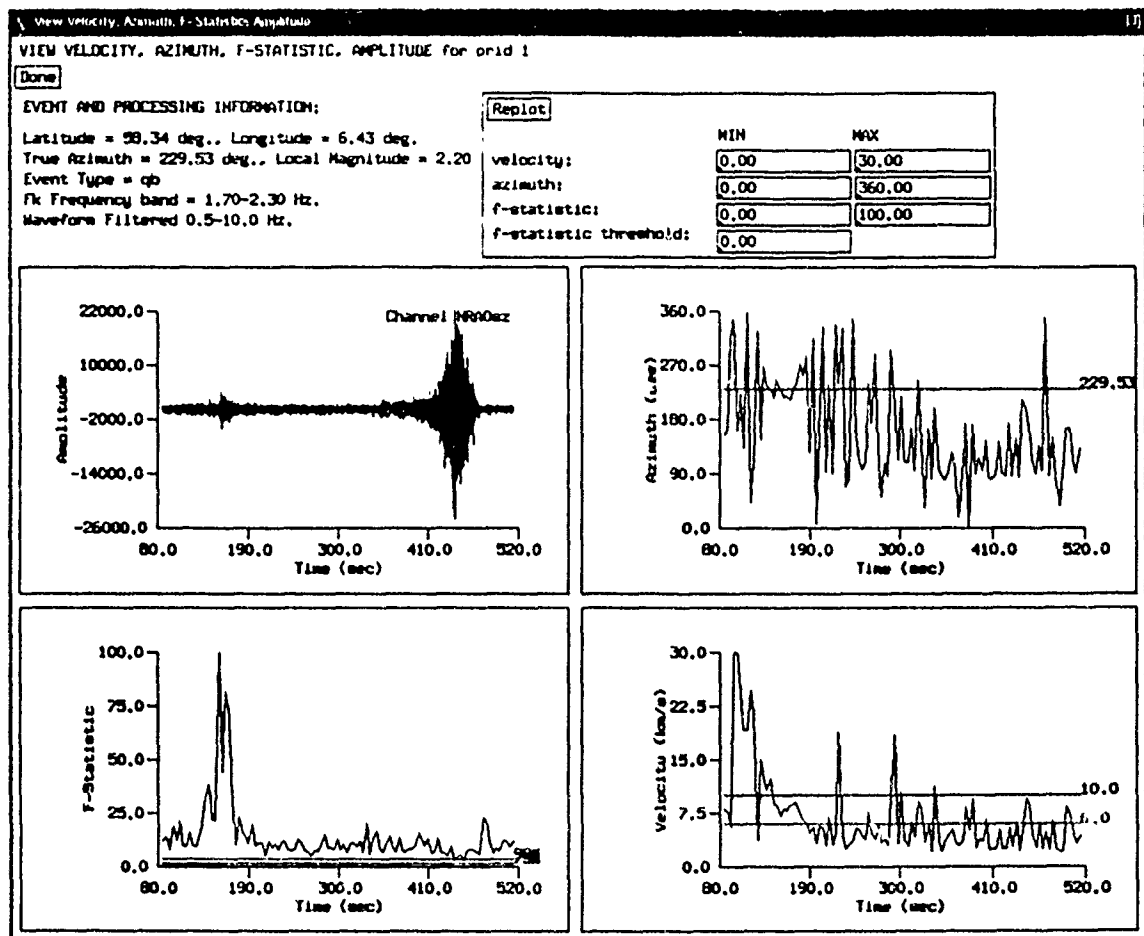
Source parameter information about the event is shown in the top left of the window. The subwindow at top right contains a set of text boxes in which the user can type thresholds for replotting. The four subwindows at the bottom are, going clockwise from the upper left, a single channel waveform, the azimuth template, the velocity template, and the F-statistic template. The horizontal line on the azimuth template indicates the true azimuth of the event, relative to the station. The two horizontal lines on the velocity template shows 6 and 10 km/sec velocities.

The template plots can be changed by entering different threshold values in the *Replot* boxes in the upper right window and then mousing on the *Replot* button. Any of the templates can be dragged with the left button of the mouse to estimate the average parameters in a time period, as shown below:
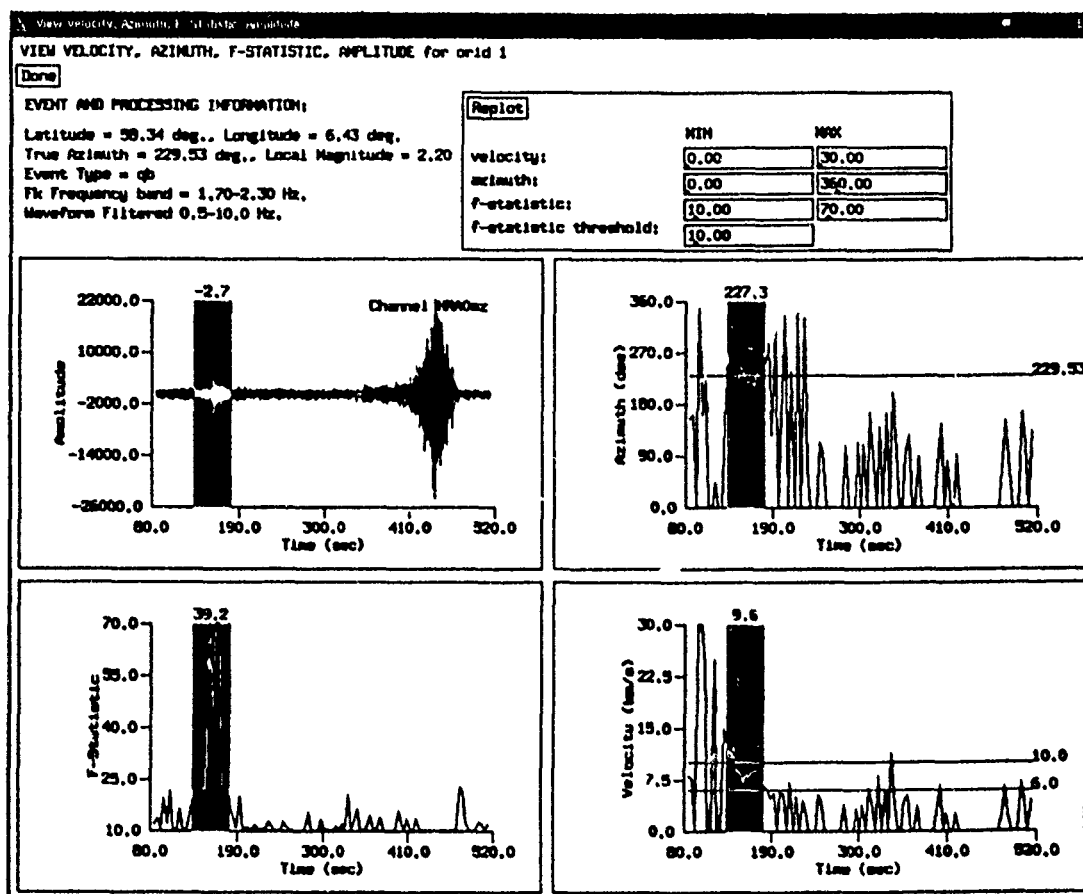
In this example, a time interval on the *Pn* wave has been selected. The selected range is darkened-in on the templates. The number in the darkened area is the average value of the template function over the selected period. Thus, as shown, the average velocity of the *Pn* wave is 9.6 km/sec, its average azimuth is 227.3 degrees, and the average F-statistic value for the FK spectral peaks is 39.1. The mouse can be used to drag other time periods any number of times to examine other parts of the seismogram.

7.4.2.3 SELECT Menu Options
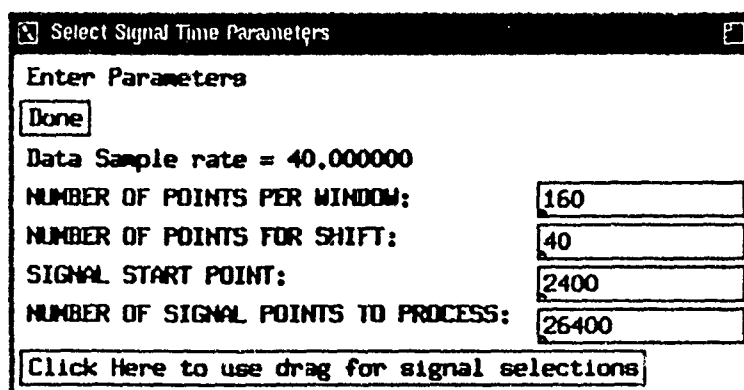
The **SELECT** menu has options for controlling the input parameters to the CFKDISPLAY process.
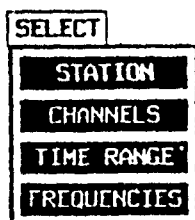
| SELECT |
| STATION |
| CHANNELS |
| TIME RANGE |
| FREQUENCIES |

STATION brings up a window listing all the stations for which waveform data is available for the event. This display is the same as that described in Section 7.2.1.3.

CHANNELS displays a scrollable window containing check boxes for all the channels available for the station. This display is the same as that described in Section 7.2.1.3.

TIME RANGE is used to set the limits on the time range for which to compute the sonogram. Selecting this option displays the subwindow shown below:

Select Signal Time Parameters
Enter Parameters
Done
Data Sample rate = 40.000000
NUMBER OF POINTS PER WINDOW: 160
NUMBER OF POINTS FOR SHIFT: 40
SIGNAL START POINT: 2400
NUMBER OF SIGNAL POINTS TO PROCESS: 26400
Click Here to use drag for signal selections

This window contains text boxes for entering the window parameters for the moving FK window. These parameter have exactly the same meaning as those in the *TIME RANGE* selection window for CFSDISPLAY, described in Section 7.4.1.3. In addition to entering the parameters by hand, they can also be selected by using mouse-drag on one of the channel waveforms, as explained in Section 7.4.1.3.

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FREQUENCIES displays a small subwindow, shown below:

```
┌─────────────────────────────────────────────────┐
│ ╲┐ Select Frequency Parameters          ·    ᠫ╗ │
├─────────────────────────────────────────────────┤
│ SELECT FREQUENCY PARAMETERS for orid 1          │
│ ┌────┐                                           │
│ │Done│                                           │
│ └────┘                                           │
│ Low Frequency (Hz.)        : ┌─────────────────┐ │
│                              │1.70             │ │
│ High Frequency (Hz.)       : ┌─────────────────┐ │
│                              │2.30             │ │
│ Low Filter Frequency (Hz.) : ┌─────────────────┐ │
│                              │0.50             │ │
│ High Filter Frequency (Hz.): ┌─────────────────┐ │
│                              │10.00            │ │
└─────────────────────────────────────────────────┘
```

The first two entries in this window set the lower and upper frequencies for the broadband FK. The third and fourth entries are for entering an optional prefilter to be applied to each channel.

7.4.2.4 EXECUTE Menu Options

```
┌─────────────────────────────────────────────────────────┐
│ ┌─────────────────────────────────────────────────────┐ │
│ │              CONTINUOUS FK for orid 1               │ │
│ └─────────────────────────────────────────────────────┘ │
│ ┌──────┐ ┌──────┐ ┌───────┐ ┌────────┐                  │
│ │ FILE │ │ VIEW │ │SELECT │ │EXECUTE │                  │
│ └──────┘ └──────┘ └───────┘ └────────┘                  │
│                      ┌──────────────┐                   │
│                      │CONTINUOUS FK │                   │
│                      └──────────────┘                   │
└─────────────────────────────────────────────────────────┘
```

The single option under **EXECUTE** is *CONTINOUS FK,* which initiates the CFKDISPLAY process using the default or user selections. The continuous FK computation can ta'.e a long time to complete. Thus, selecting *CONTINUOUS FK* starts up a subprocess which runs in the background independently of CFKDISPLAY. The *CONTINOUS FK* option remains displayed until this process has begun. When the process ends, a process display icon, discussed in Section 3.5, will be displayed which will be mouse-sensitive. This icon will be displayed in the upper right of the monitor, regardless of whether or not the original CFKDISPLAY process is still running. If the icon is moused, the *CFK PLOTS* process, which also runs under the **VIEW** menu, will be started which can be used to view the results.

7.4.3 COMPARE

The COMPARE function in ISEIS allows th' .nalyst to overlay waveforms from the current event with those from the reference events ior the purpose of visual comparison. The waveforms to be compared can be selected for different channels such that the channels for the current event are the same as those for the reference event. Only waveforms for different events

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recorded on the same channel at the same station or array can be compared. Waveform prefilter and zooming capabilities are also provided.

The COMPARE function can be invoked from the Spreadsheet in the **PROCESS** menu by selecting the *COMPARE* option. Events to be displayed in COMPARE are those selected in the Spreadsheet when the process is initiated. Current and reference events are identified from menu options in the COMPARE interface itself. When the COMPARE process is initiated, a subwindow is created containing the COMPARE menubar, which has the standard menus discussed above in Section 7.1

7.4.3.1 FILE Menu Options

This menu is exactly the same as that for the IBEAM and FSDISPLAY functions (see Section 7.2.1.1). Currently, the only option which has been implemented is *QUIT*, which exits the COMPARE process and returns control to the Spreadsheet.

7.4.3.2 VIEW Menu Options

This menu specifies what functions are to be compared.

The single option under **VIEW**, *Waveforms*, displays waveform plots which can be displaced laterally and vertically for the purpose of overlaying. When this menu option is selected, the following subwindow is produced:

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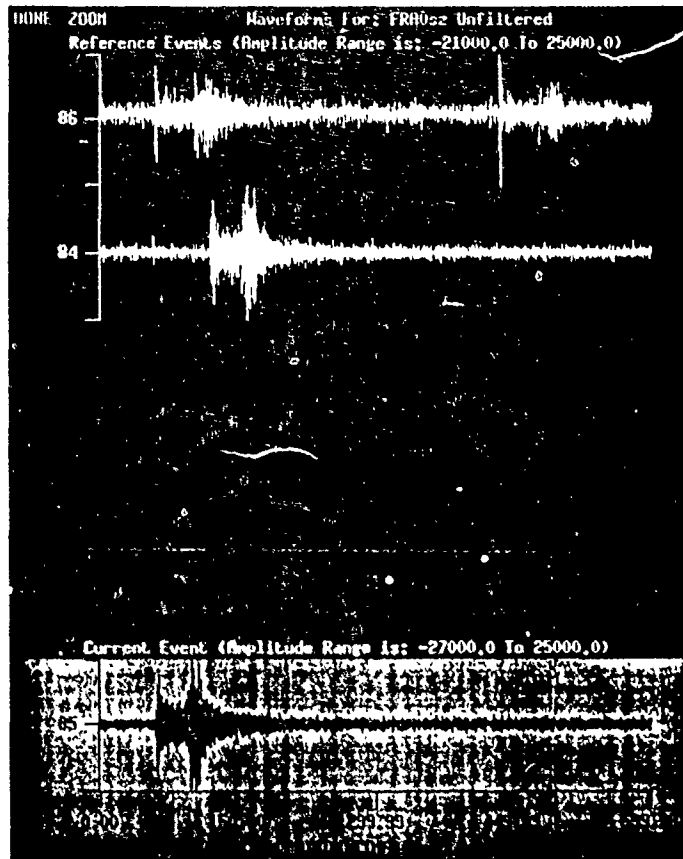
In this overlay display, the current-event waveform is plotted at the bottom and the reference-event waveforms are plotted above the current event. Any number of reference events can be displayed at the top of the window, which can be scrolled. The waveforms can be different lengths and the signal start times may be different. The Zoom function is provided to re-window the waveforms to align the signals and to expand the plots, if desired. The procedure is to select the time interval on the current event at the bottom and for the reference events at the top by dragging on the waveforms while holding down the middle mouse button. The selected regions are then highlighted, as shown below:
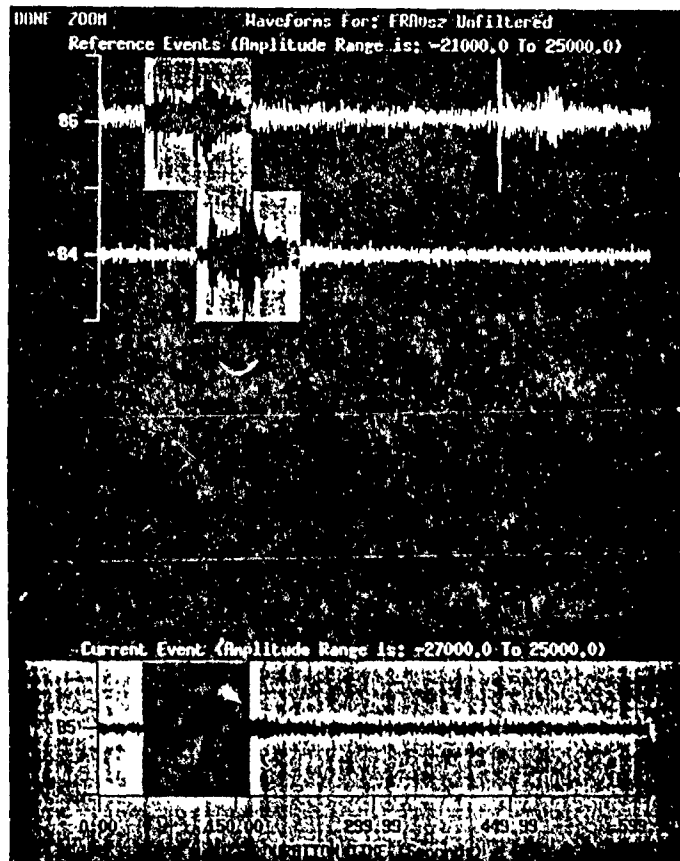
When the *ZOOM* button at the top of the window is pressed with the left mouse, the plots will be redisplayed but with the selected region expanded, as shown below:
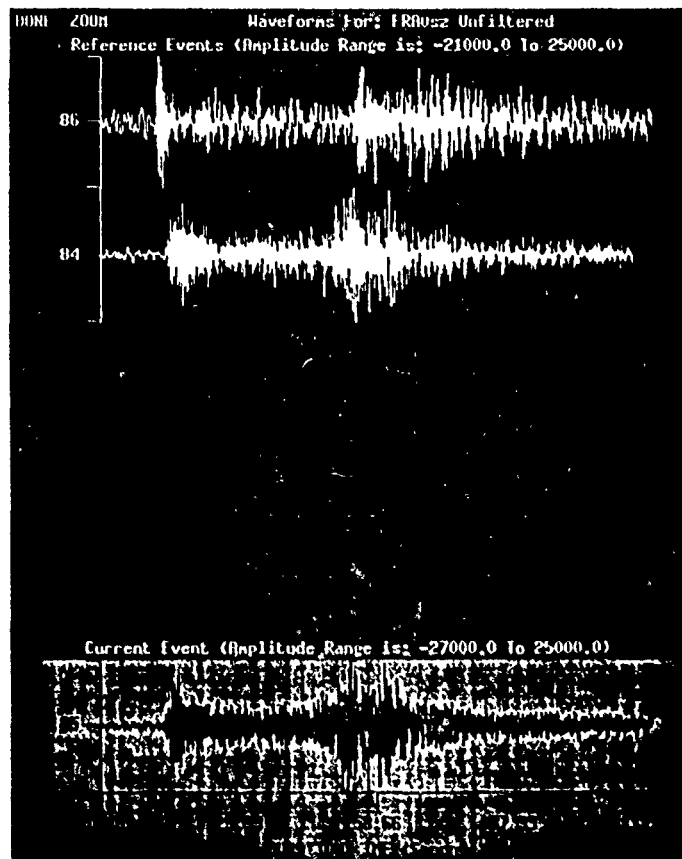
Reference events can be selected and pulled down to overlay on top of the current event. The procedure is to first select the desired reference event by moving the mouse to the reference event waveform and pressing the left mouse button. While holding down the left button, the reference waveform can then be dragged down vertically to overlay on top of any of the other reference events or the current event at the bottom, as shown below:
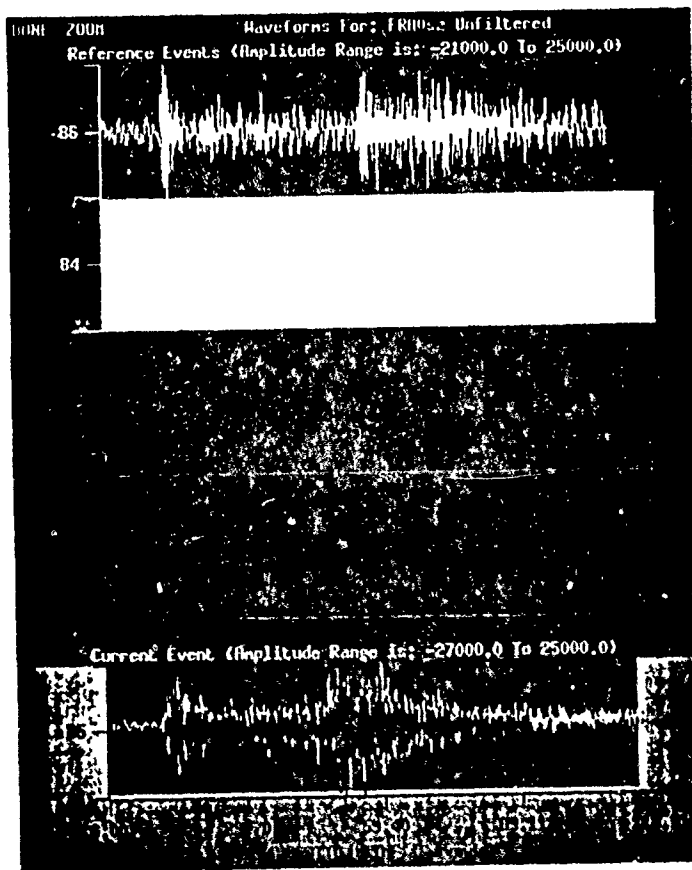
The waveform can also be moved laterally, as well as vertically, to **further adjust the overlay**, while still holding down the left mouse button. When the left mouse **button is released**, the reference-event waveform will snap back to its original position.

7.4.3.3 SELECT Menu Options

The **SELECT** menu options specify which waveforms are to be compared.
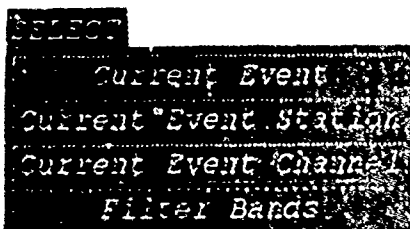
Current Event allows the user to specify a different current event from the one chosen on the Spreadsheet. The events on the Spreadsheet are displayed in a scrollable list which can be selected by the user. The selected event then becomes the new current event.

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Current Event Station allows the user to specify the station for the waveforms to be displayed. This display is the same as that described in Section 7.2.1.3.

Current Event Channel allows the user to specify the channel of the selected station to display for both the reference and current events. This display is the same as that described in Section 7.2.1.3.

Filter Bands allows the user to select the parameters for the prefilter to be applied to the waveforms. Selection of this options produces the following window to be displayed:

```
       COMPARE FILTER PARAMETERS (Hz)

  Low Frequency Band  [  |  High Frequency Band
    0.60                      8.00

FILTERING DISABLED

DONE
```
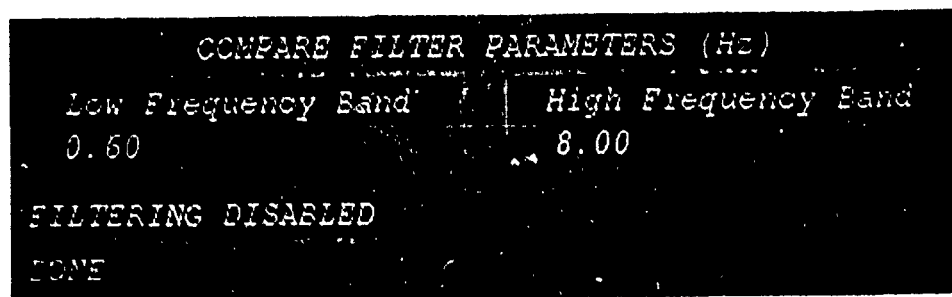
The frequency limits for the bandpass filter can be typed into the boxes labeled *Low Frequency Band* and *High Frequency Band*. As shown, the default values are 0.6 to 8.0 Hz. Mousing on the *Filtering Disabled* will cause no filter to be applied. This button can be toggled to enable filtering after disabling, if desired. The window is removed by mousing on the done button. The waveforms will be filtered before they are displayed.

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